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Design, development and field testing of an advanced cardamom curing chamber prototype for Sikkim (Pilot Scale Phase)

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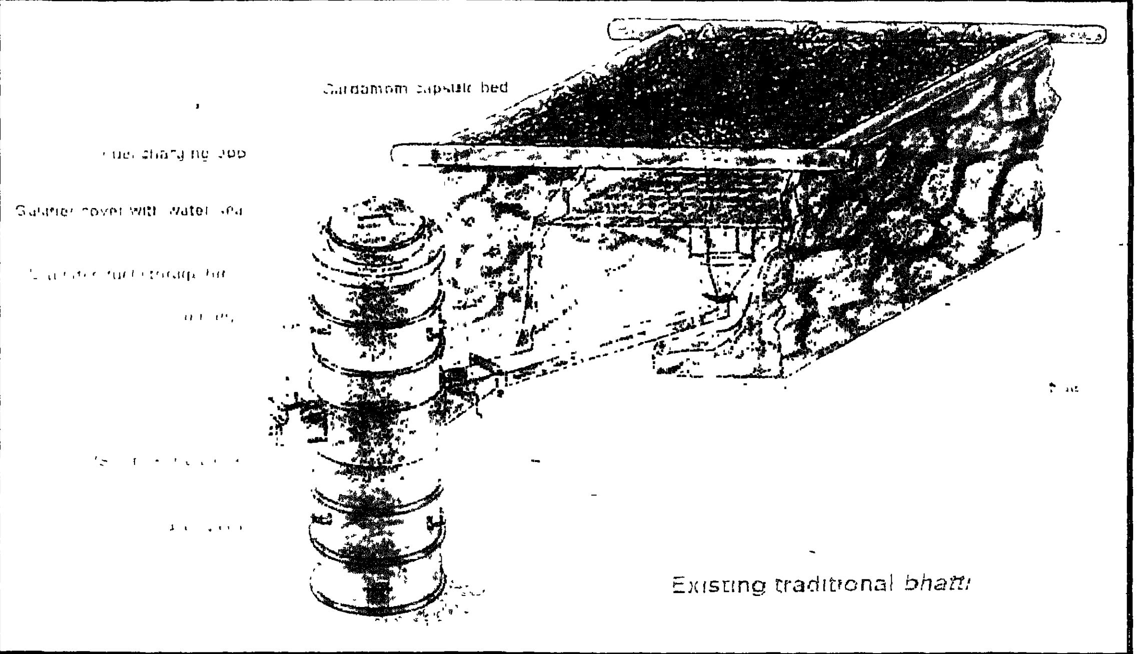

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CHAPTER 1

Introduction

India is the largest producer of large-cardamom in the world with a share of 54%, followed by Nepal (33%) and Bhutan (13%). Large-cardamom is a major cash crop of Sikkim with annual production of over 3500 MT from total cultivation area of 23,500 ha. More than 85% plantations are very small (with area < 2 ha) located in remote hilly areas[1]. For long duration storage and for bringing out the characteristic aroma, cardamom capsules have to be dried to bring down the moisture content from about 70-80% (w.b.) to below 10% (w.b.). Presently cardamom is dried using a traditional *bhatti* system.

1.1 Traditional *bhatti* system

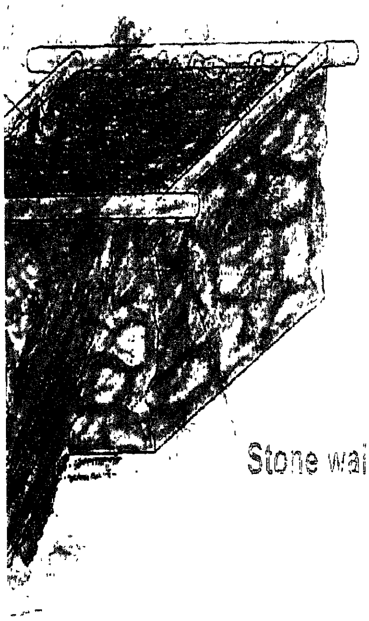
Traditional *bhatti* consists of thick stone/rock wall structure with a large opening on one side for burning woodlogs (See Figure 1.1). Cardamom is loaded as a thick bed on a wiremesh/bamboo-mat platform. This primitive, inefficient, smoking technique used for curing consumes a huge quantity of wet wood logs and results in poor quality of dried cardamom.

Detailed energy audits carried out on existing traditional *bhatti*s indicate that they operate with poor thermal efficiencies of the order of 5-15% resulting in an estimated annual fuelwood wastage of about 20,000 MT in Sikkim alone[1]. Lack of control on fire causes localized heating of cardamom bed resulting in charring of capsules and loss of its volatile oil content which gives the characteristic aroma to dried cardamom.

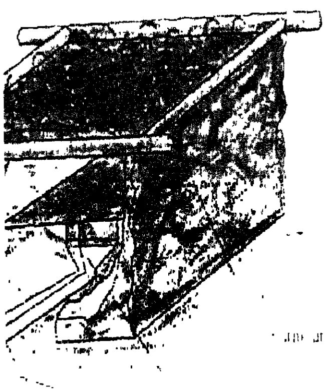
There is a good scope to increase the export of large-cardamom with a corresponding need to improve its quality (maintaining natural reddish colour and volatile oil content) which can fetch a premium price. Technology upgradation for curing of large-cardamom in Sikkim will also improve the overall energy efficiency, helping preservation of the state's natural forest.

1.2 Gasifier system for drying large-cardamom

The gasifier converts wood fuel into the more convenient gaseous form, which can be burned under controlled conditions to provide heat required for removing moisture in the cardamom drying process. In the Action Research Phase of the ISPS sponsored project, TERI has developed a simple, low cost gasifier based system for curing of large-cardamom in Sikkim (See Figure 1.2).



bhatti system for drying large-cardamom



Mark-1) developed in Action Research Phase

This system has several advantages as listed below:

- Better quality of cardamom as gaseous fuel is burnt in the burner located inside *the bhatti*
- It can be used as an add-on system to existing *bhattis*
- Low incremental cost (used oil barrel, fire clay lining)
- Simple design; can be fabricated in workshops of rural areas
- Better thermal efficiencies due to controlled burning rates, small insulated combustion chamber, controlled excess air levels

In the first year of the action research phase a prototype unit (Mark-0) has been developed at TERI which was successfully field tested at Kabi in north Sikkim during the harvesting season of 1996. Based on the feedback received, the system design was modified further to make it easy-to-fabricate as well as user friendly, and easy-to-transport in hilly regions for installation.

During the harvesting season of 1997 the improved system (Mark-1) was successfully field tested at four sites (1 each in all four districts of Sikkim) for extended field testing and for obtaining sufficient quantity of improved quality cardamom for test marketing.

The major achievements of the action research phase are[2]:

- improved thermal efficiency resulting in more than 60% fuel saving
- improved quality of dried cardamom
    - retaining its natural reddish colour without charring of capsules
    - higher volatile oil content without burnt/char smell
- trial test marketing indicated that improved quality Sikkim Grade I cardamom obtained in the gasifier system can fetch a good premium making it economically attractive.

During trial test marketing of cardamom almost all traders expressed their opinion that a minimum marketable lot (a few truck loads) is necessary in order to get the real picture of how much premium the improved quality cardamom can fetch in the market.

The current phase of the project is aimed at carrying out the pilot scale phase of technology development process. This is expected to help in testing/verifying user acceptability of the system and marketability of improved quality cardamom along with quantification of financial benefits of the system.

1.3 Objectives

The objectives of the pilot scale phase are to test the marketability and user acceptability of the system by promoting around 15 units in Mangan region of north Sikkim. Financial benefits from the operation of the system and marketing of the product will also be studied. Based on the feedback received, a strategy for large scale promotion of the advanced gasifier based system in Sikkim will be proposed for consideration.

1.4 Work elements

The work elements identified in the original project proposal to achieve the above objectives are listed below[3]:

1. Improvement in existing Mark-1 prototype design for pilot scale plant.
2. Selection of sites for pilot scale plant(s) in Mangan area of north Sikkim.
3. Arrangements for system operation by producers through agreements and centralized training of operators.
4. Fabrication, installation and commissioning of Mark-2 pilot scale units at selected sites in north Sikkim.
5. Assistance to farmers for marketing improved quality cardamom.
6. Assist previous farmers to continue using the gasifier based system.
7. Study on improving *bhatti* design in the field through trials.
8. Monitoring the systems to assess financial benefits, commercial feasibility and dissemination potential of the system.
9. Formulating a strategy for large scale promotion of advanced gasifier based dryer system in Sikkim.
10. Documentation of the project findings.

This report gives a detailed account of the project work carried out during the Pilot Scale Phase of the project in order to achieve the above objectives.

CHAPTER 2

Development of improved (Mark-2) prototype unit

2.1 Feedback received from Action Research Phase

2.1.1 From farmers during field testing of Mark-1 unit

During the course of extensive field testing of the Mark-1 prototype unit in all the four districts of Sikkim, the system operation was monitored round the clock for several batches for its field performance. Another major objective of round the clock monitoring of the system in the field was to get the much needed feedback from the user (farmers/operators) of the system to help to improvise system design so as to make it user-friendly and acceptable to all farmers.

Technically the Mark-1 system performed very well during Action Research Phase, proving substantial improvement in quality of dried cardamom and confirmed fuel wood saving potential. However farmers felt that a few minor improvements in design could be attempted and more operational and maintenance convenience needs to be incorporated in the present design to make it more user-friendly and acceptable. The valuable feedback received from the farmers is summarized below:

- Difficulty in making/keeping fuel charging door leakproof during system operation. Damaged/burnt gland rope used in sealing the door causes gas leakage from edges.
- Some farmers expressed fear that during round the clock operation of system, specially in the late night hours, it is difficult to strictly adhere to 1.5-2 hours fuel charging interval. In case one fuel charging cycle is missed it may exhaust all the fuel in the gasifier, making restarting of the gasifier necessary. This is not only time consuming but also needs more attention of the operator.
- Farmers expressed concern over easy availability of a few items in the system, such as gland rope for making the door gas-tight, ceramic blanket insulation for insulating gas carrying duct etc., as these would be difficult to replace in remote hilly areas which are not easily accessible.
- Farmers said that all system components should be designed in a much simpler way so that repairs will not be needed for several years. They felt that the lever mechanism used for locking and unlocking the fuel charging door in Mark-1 design is much easier to use compared to the earlier version but may need frequent maintenance as several welding joints and hinges are involved.

2.1.2 From participants of Project Review Workshop

Project review workshop organized at the end of Action Research Phase was aimed at critical review of design by various agencies and users involved in development of large-cardamom activities in Sikkim. Their active participation in the discussions helped in obtaining useful feedback for further development of the project/system design.

Some major suggestions/points made by various participants are summarized below[2]:

- Improve the Mark-1 system for increasing
  - durability
  - reliability of operation
  - user friendliness
- Try to use local material as far as possible e.g. for duct insulation.
- Improve the *bhatti* design too in order to improve the overall system performance.
- Modify *bhatti* design to create space for packing wood for drying.
- Modify *bhatti* design to arrange cardamom bed in several thin/mono layers.

2.2 Development of improved Mark-2 system design

After taking into consideration the above feedback received from the farmers and other participants, it was decided to focus R&D efforts on the following system component design:

- Gasifier fuel charging door
  - to make fuel charging process quick and easy
  - to avoid gas leakage
  - to make design simple to fabricate
  - to make design rugged enough for minimizing maintenance and repair requirement.
- Gasifier design to increase fuel storage capacity so as to increase fuel charging interval.
- Improved burner design for more uniform heating of cardamom bed.
- Use of local material for duct insulation.

2.2.1 Use of water seal for gasifier fuel charging door

The operational inconveniences in fuel charging can be summarized as follows:

- difficulty in making the fuel charging door leak proof (See Figure 2.1).
- unavailability of gland rope used in the fuel charging door locally.
- sometimes the flame comes out from fuel charging door during charging and while locking the door with the lever mechanism.

In order to overcome these problems it was decided to use a water seal in the fuel charging door of the gasifier. Water is placed in the annular space and a top cover is placed in it as shown in Figure 2.2. Water level is maintained such that it is more than the pressure difference between inside and outside the gasifier. Thus no gas can escape through the water seal. This simple principle helps in making the fuel charging door leak-proof at the same time allowing quick opening and closing of the door. Figure 2.3 shows a photograph of the water seal fuel charging door and Figure 2.4 shows the complete gasifier incorporating the modified fuel charging door.

The fuel charging mechanism with water seal helped in eliminating gas leakages and reducing the time for fuel charging. It also gave scope for widening the fuel port enabling the operator to charge longer pieces of fuelwood smoothly. The only drawback of the system was the need to keep adding water in the water seal to makeup for evaporation losses. It was more pronounced when the fuel level inside the gasifier goes down, exposing the metallic door to hot fuel bed.

2.2.2 Development of double barrel gasifier design

In order to minimize the problem of frequent addition of make up water and shorter interval of fuel charging it was decided to use a double barrel gasifier so that the storage capacity of the hopper is increased. Thus an empty barrel open from both the ends was added to the top of the single gasifier design and the water seal cover was correspondingly moved up. Hence there was less chance of exposure of the top metallic cover to hot fuel bed and thus evaporation losses in the water seal are minimized. The make up water has to be added now only at the time of fuel charging, the duration of which is now increased to 6-7 hours.

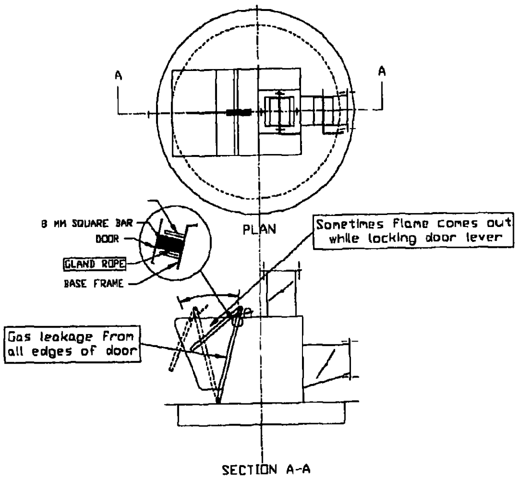

A
A
8 MM SQUARE BAR
DOOR
GLAND ROPE
BASE FRAME
PLAN
Sometimes flame comes out while locking door lever
Gas leakage from all edges of door
SECTION A-A

Figure 2.1. Schematic explanation of the operational inconvenience brought to notice by farmers

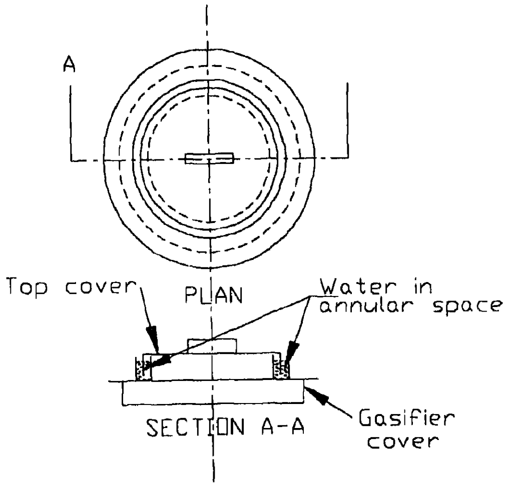


Figure 2.2. Schematic diagram of water seal fuel charging door

Figure 2.3. Gasifier top cover with water seal fuel charging door arrangement

Figure 2.4. The gasifier incorporating the modified fuel charging door

Also, an opening was provided diametrically opposite to the gasifier outlet for cleaning the duct with the help of a long rod or bamboo without dismantling the system. The chimney outlet is now taken from the side wall of the connecting piece between the two barrels. The top cover is sized so that it can be placed either on the top barrel or on the top of the connecting piece, thus giving the farmer an option to use either a single or double barrel (See Figure 2.5).

The photograph in Figure 2.6 shows the components of the double barrel gasifier system which consists of (I) original single barrel gasifier as in the earlier design, (ii) second additional barrel, (iii) connecting MS piece with chimney and gas outlet duct, (iv) top cover with water seal. The assembled double barrel system is shown in Figure 2.7. The schematic drawing showing all the gasifier system components in the form of exploded view is given in Figure 2.8.

2.2.3 Use of local material for duct insulation

In the earlier system, a ceramic blanket was used as an insulating material in order to keep the gas-carrying duct hot so as to minimize tar condensation. As a cheaper alternative a locally available cane-like material known as *Sarkhanda* (*saccrum munja*) was tried out. A thin mud-layer was applied on the duct first and after wrapping a layer of *sarkhanda* curtain, a thick mud layer is again applied to protect it from direct exposure to fire and to increase its life (See Figure 2.9). Since *bamboo* is more common in Sikkim, trials were made with *bamboo* also for insulating the gas-carrying duct. Figure 2.10 shows the gas carrying duct insulated with *bamboo*.

2.2.4 Modifying the burner design and flare arrester

After successful field testing of a multi burner system at Mangan during the action research phase, it was decided to conduct long duration tests at TERI's Gual Pahari campus so as to optimize the design (e.g. diameters and number of burner ports) and to fine tune its design to make it more user friendly for pilot scale plants. Through extensive trial experiments, the burner port design was optimized so as to give desired fuel consumption rates of the order of 10-15 kg/h. Side openings with end plugs were provided in all the four ends of the secondary gas duct and at the end of the primary gas duct to facilitate cleaning. Also a simple burner shield was made for all the burners. Figure 2.11 shows the multiple burner system in operation at TERI's Gual Pahari campus.

In order to hold a larger (5 ft × 5 ft) flare arresting sheet (as there are five burning ports now covering larger *bhatti* area) in between the gas burners and the cardamom bed, a stand was fabricated and supported on the four arms of the multiple-burner as shown in Figure 2.12. The exploded view of the producer gas multiple burner is given in Figure 2.13.

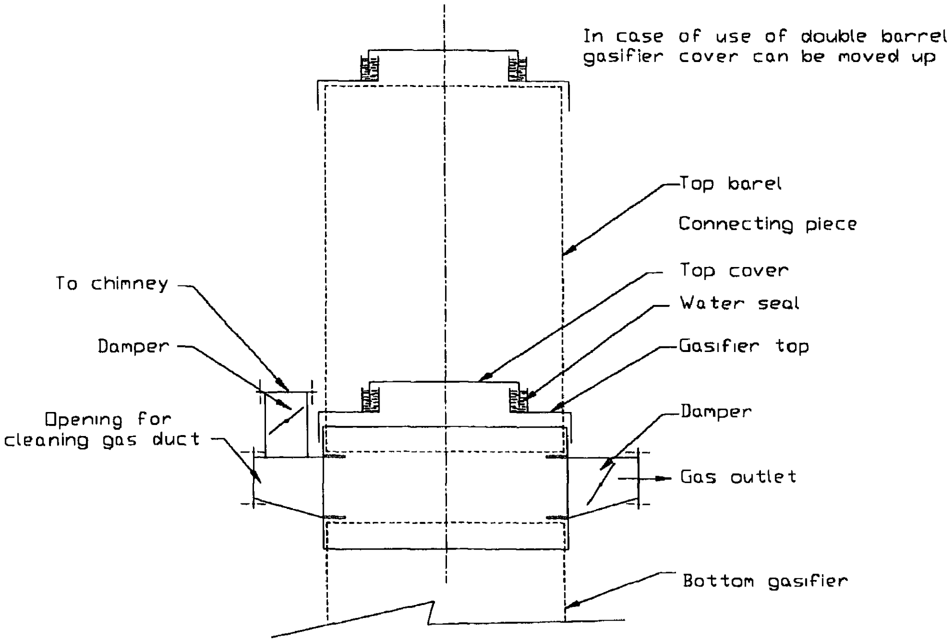


Figure 2.5. Schematic diagram of barrel connecting piece

Figure 2.6. Components of double barrel gasifier system

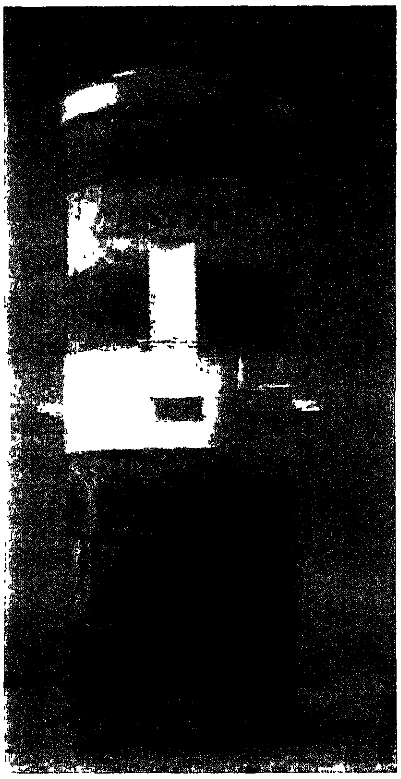


Figure 2.7. Assembly of double barrel gasifier system

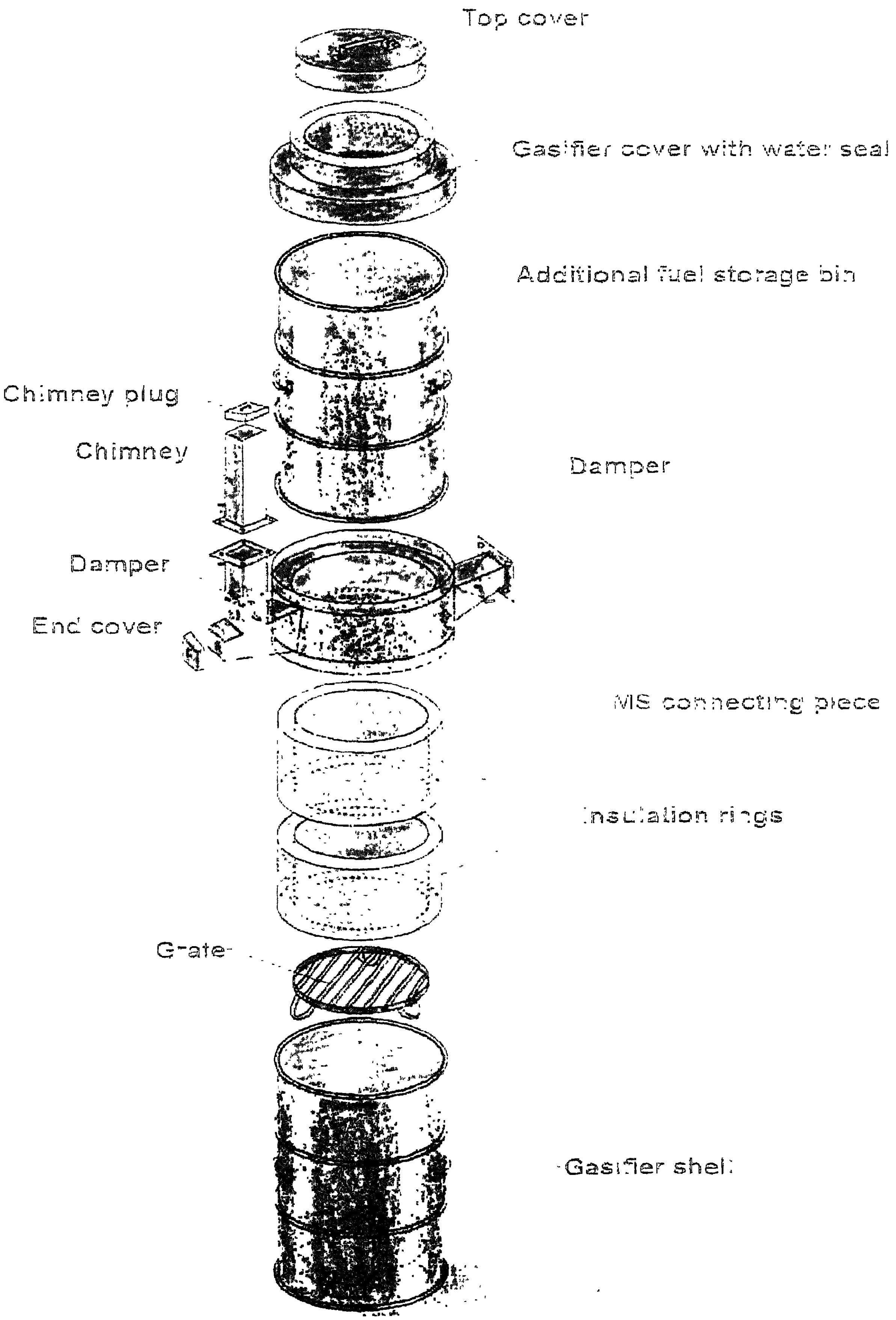


Figure 2.8. Exploded view of Mark-2 gasifier system

Figure 2.9. Use of *Sarkhanda* with mud-layer as duct insulating material

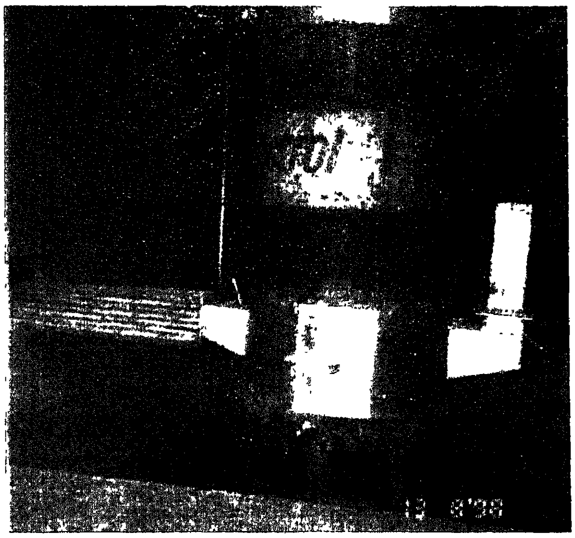


Figure 2.10. Use of *bamboo* mat as duct insulating material

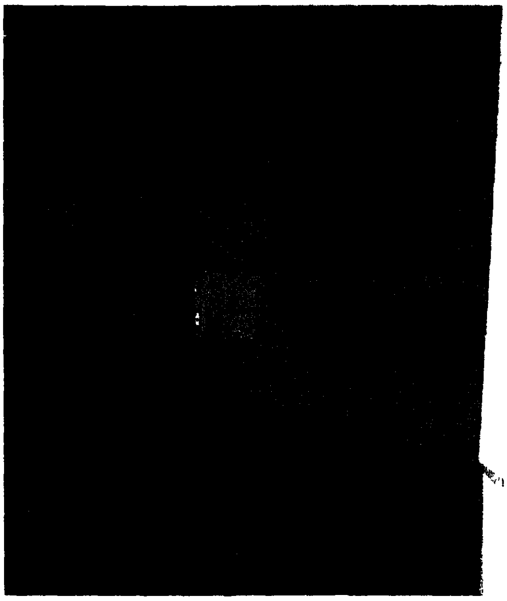


Figure 2.11. Multiple producer gas burner system in operation

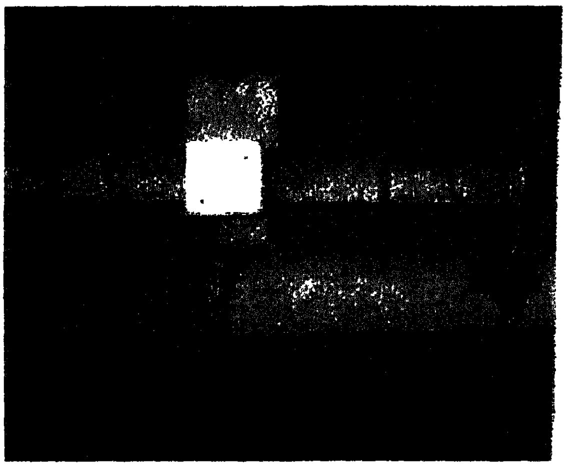


Figure 2.12. Closeup of the stand made to hold flare arresting perforated sheet

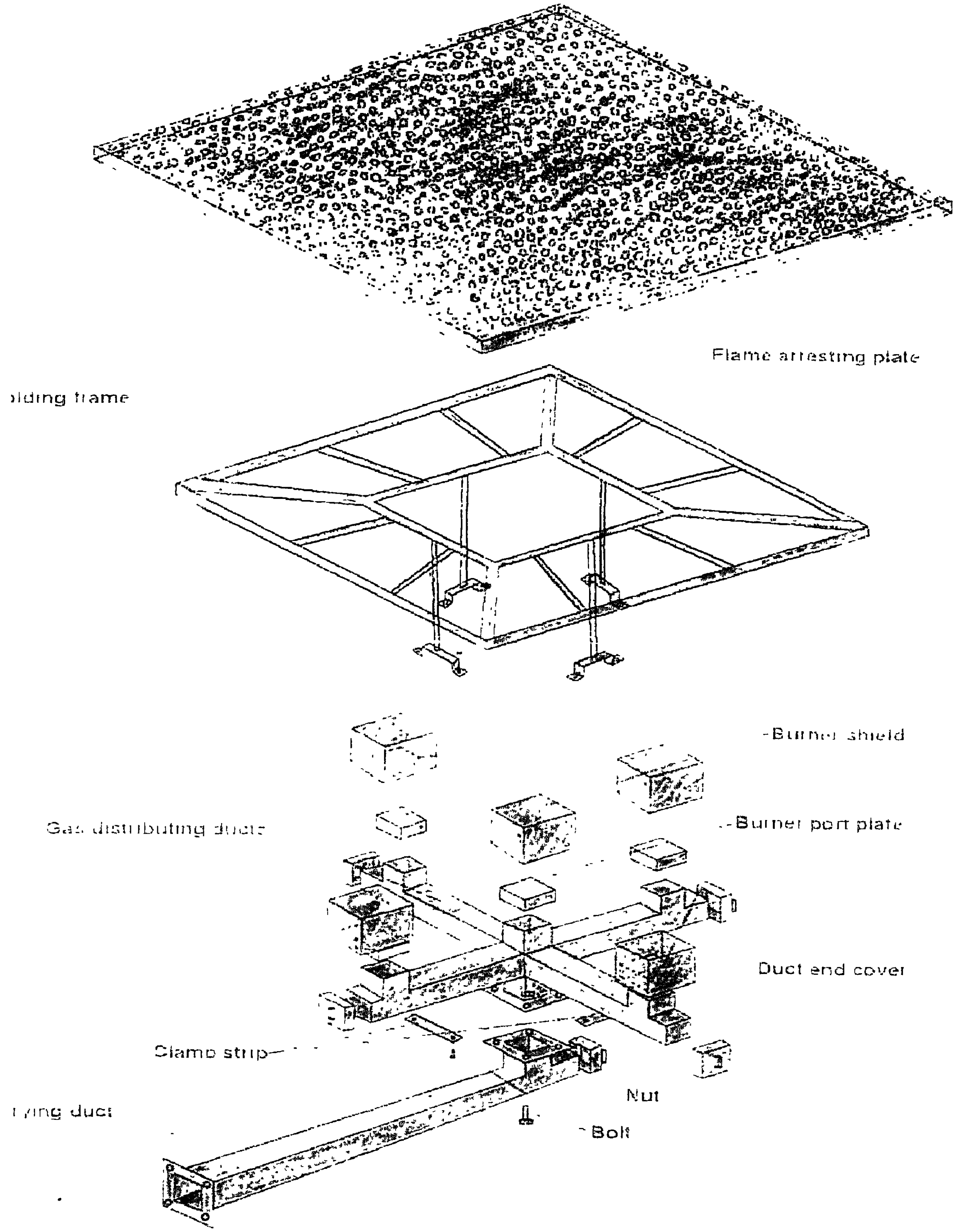


Figure 2.13. Exploded view of multiple producer gas burner

2.3 Development of improved model *bhatti* design

Due to unpredicted rains this year, the yield was only around 1/4th of the normal value. So the farmers could not use the *bhatti* for more number of batches. Also, trials using several mono layers and for different bed thickness in the same *bhatti* (to minimize variations in operating parameters) could not be tried in the field. However, trials were made with varying gaps between burner and cardamom bed and with different bed thicknesses in different unit so as to judge its effect at least qualitatively. It was observed that though increasing the gap between the burner and cardamom bed results in a slight increase in drying time, it gives more uniform drying and better colour/appearance. This is probably due to a better mixing of flue gases and surrounding air resulting in a uniform temperature across the entire cross section, and thus minimizing chances of localized heating of capsules.

An improved design of the *bhatti* was constructed at the Gual Pahari campus of TERI for trials. It consists of 7 ft tall room of size 8 ft × 8 ft with open top and 9 inch thick brick wall on all four sides. The wiremesh for loading cardamom was located on top of the walls. About 1 ft tall brick wall border was made above the wiremesh to hold the cardamom on it. In the front end, a 1.5 ft wide double door (longer bottom door and a smaller top door) arrangement was made with MS. The bottom door can be closed for most of the time during the use of *bhatti* for drying cardamom and the top smaller door can be used for igniting flame in the burner and for monitoring the flame conditions. The bottom door can be used for going inside the *bhatti* at the time of system installation and at the time of dismantling the system as well as for any servicing requirement. The *bhatti* cross sectional size can be in the range of 8 ft × 8 ft to 10 ft × 10 ft for drying about 400 to 600 kg raw cardamom capsules per batch respectively. Wiremesh platform for loading cardamom bed needs to be located at about 7 ft above the gasifier bottom in order to accommodate gasifier-burner system and to have minimum gap of 1.5 ft between cardamom bed and flare arresting sheet and between also between flare arrester and producer gas burner top.

This design also gives ample space inside the *bhatti* below the burner level which can be used to store and dry fresh wood stock by utilizing the radiant heat of the burner received by *bhatti* walls and floor, which can be used in subsequent batches. Also by replacing the wire mesh with a GI sheet, the *bhatti* can be converted into a store room. Figure 2.14 shows the schematic diagram of the model improved *bhatti* design suitable for gasifier system showing the overall arrangement and layout. Photographs in Figures 2.15-2.16 show the prototype of improved *bhatti* design constructed at TERI's Gual Pahari campus for carrying out trial testing.

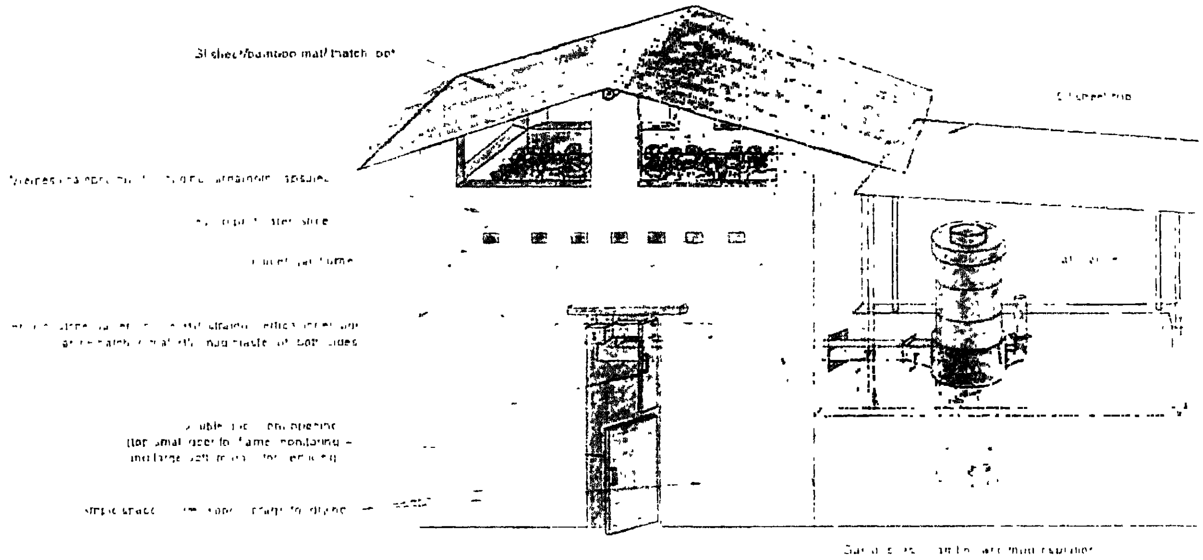
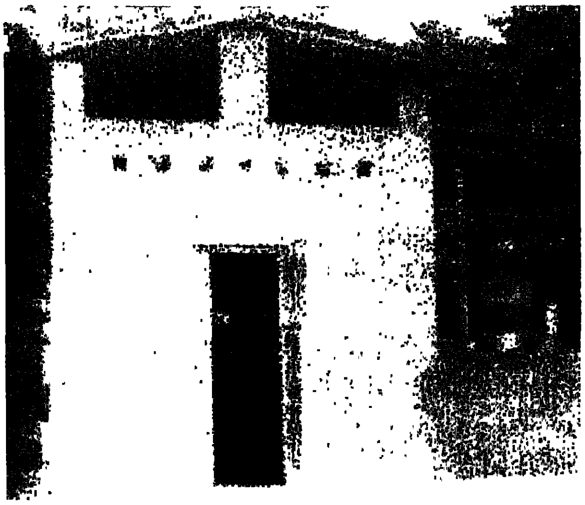


Figure 2.14. Schematic diagram of model improved *bhatti* design



igure 2.15. Mark-2 gasifier and multiple as burner in operation at improved *bhatti*

Figure 2.16. Aerial view of improved *bhatti* constructed at TERI's Gual Pahari campus

CHAPTER 3

Preparations for pilot scale phase field testing

3.1 Selection of sites for pilot scale plants in Mangan

The horticulture officer (HO) of north Sikkim was requested in advance, through Mr U Bhutia of horticulture department, to prepare a short-list of farmers willing to participate in the pilot scale trials during the harvesting season of 1998.

On reaching Sikkim a visit was made to Mangan and a meeting of interested farmers was held with the help of HO and Mr P G Tenzing. The TERI team explained the progress made so far during the action research phase and the details of further improvements made on the system. Sketches, drawings, and photographs were used for explaining the principles and operation of the system to the farmers.

A list of farmers who agreed to make arrangements for dry wood pieces in time i.e. before actual harvesting of the crop in their field was prepared. TERI agreed to provide the system components and bring it to Mangan. Table 3.1 summarizes the details of the farmers selected for field testing and the information provided by them about probable harvesting time, and quantity of cardamom which would be provided for trials.

Table 3.1. Details of farmers selected for pilot plant gasifier system field testing as on 15/09/98

Sr. No.	Name	Particulars	Location of farm	Expected season	Expected produce (dry bags)	Wood availability status
1	Mr Tenzing Dadul (Ex-MLA)	Ph. 34287 (Big house in Bazar)	Lingza, Upper Dzongu	After Dasahara- till Oct end	40-50 bags	Dry wood ready
2	Mr P G Nangpa	Ph. 34351 (Garage near Himalaya Hotel)	Lingza, Upper Dzongu	After Dasahara- till mid Nov	50-60 bags	Dry wood ready
3	Mr Thendup Ripon	Ph. 34284 (C/o Himalaya Hotel, Karma Yezher, HO)	Thingchim, near Rangrang bridge	After Dasahara- till Oct end	12-13 bags (can dry others too)	Yet to dry wood
4	Mr Pemza Tenzing	Ph. 34241 President AILCGA, Board Member, Mangan Bazar	Thirung, above Malling	End Oct- Mid Dec	15 bags in gasifier	Yet to dry wood

Sr. No.	Name	Particulars	Location of farm	Expected season	Expected produce (dry bags)	Wood availability status
5	Mr Zigmi Lachenpa	Ph. 34209 (Near SNT Bus stand)	Salim Pakyal (Dzongu)	November	20-25 bags	Yet to dry wood
6	Mr Zigmi Ongda	Ph. 34372 (Samar House)	Kaluy, above Nampthang, Ambithang	End Oct-Mid Nov	8-10 bags (8-10 bags from next farm)	Yet to dry wood
7	Mr Karma Zongtenpa	Ph. 34363 (Mangan Bazar)	Quyring, near Manul	Mid Oct-Mid Nov	20-25 bags	Will take from stock at Mangan
8	Mr Mark Tshering	Ph. ----- (Mangan Bazar)	Ravang khola, near old market Singhik	After Dasahara-till Oct end	10-15 bags	Will take from home
9	Mr Ugen Palzor	Ph. 34324 (Khola House near SBI)	1st in Mangan for demo then will shift to Manul	Mangan: October. Manul: Nov-Dec	Mangan: 2-4 bags Manul: 90-100 bags	Will be arranged in time
10	Mr Topgay Kazi	Ph. ----- (Malling Mangan)	Malling Mangan	Mid Oct-Mid Nov	12-15 bags	Yet to dry wood
11	Mr Pentook Kazi	Ph. ----- (Mangan Bazar)	Lantay Khola, Manul Mangan	End Oct-end Nov	20-25 bags	Yet to dry wood
12	Mr Sonam Dadul	Ph. 34329 (Mangan)	12th mile Dzongu	Mid Oct-Mid Nov	50-60 bags	Yet to dry wood
13	Mrs Tashi Lahmo	Ph. ----- (Mangan Bazar)	Naga	Mid Nov-mid Dec	50-60 bags	Yet to dry wood
14	Mr Karma Gyatsen	Ph. ----- (Mangan Bazar)	Naga	Mid Nov-mid Dec	30-40 bags	Yet to dry wood
15	Mr Lakchung Bhutia	Ph. ----- (Thingchim)	Thingchim, near Rangrang bridge	After Dasahara-till Oct end	30-40 bags	Will be arranged in time
16	Mr C T Kazi	Ph. ----- (Mangan Bazar)	Above Malling	End Oct-end Nov	30-40 bags	Will be arranged in time
17	Mr P G Tenzing	Ph. 34204-5 (Pentok Mangan)	Pentok	End Oct-end Nov	30-40 bags	Will be arranged in time

3.2 Agreement for operation of the gasifier systems by farmers

In order to ensure smooth conducting of field tests at all selected sites, formal agreements were made between TERI and selected farmers with Senior Project Officer (Spices), Horticulture Department and HO Mangan as witnesses to these agreements. The salient features of these agreements are as follows.

TERI offers:

1. To supply one set of gasifier system for coupling to the existing *bhatti*. The cost of the system (which includes the gasifier, grate, castable rings, gas duct, burner and flare arresting sheet) will be borne by TERI. It includes cost of materials, fabrication of components and transportation to Mangan.
2. To give training to the system operators in the field of selected farmers with regard to installation and operation of the gasifier system. This will be done during a centralized training session which will be organized at one of the testing sites.
3. To provide technical back up support to the selected farmers and their field operators so as to help them in overcoming the problem faced during operation of the system. For this TERI's technical staff will be available at Mangan during the harvesting season.

The owner of the *bhatti* agrees to offer the following facilities to TERI:

1. Ensure supply of sufficient quantity (about 250-300 kg per batch of 400 kg fresh capsule) of dry firewood and get it cut in the required size (3-4 inch in size and 8-9 inch in length) for use in gasifier. This will be done well in advance (preferably 3-4 weeks) before actual commencement of the first batch of drying.
2. Modify the existing *bhatti* as per instructions of TERI professionals so as to improve its performance and to install the gasifier. The manpower and local civil material required to carry out the modification will be provided by the farmer.
3. Provide the manpower (a) to shift the system components to actual *bhatti* site in the field, (b) to carry out modifications in the existing traditional *bhatti*, © to install the system at site, (d) to operate the system for drying cardamom using the gasifier system.
4. Provide other facilities such as shed over the *bhatti* (preferably permanent but at least temporary), electricity connection near *bhatti*, if available, from nearby place.
5. To dry the cardamom capsules completely to bring down moisture content below 10% (w.b.) so as to enable its safe storage for long duration without fungus.
6. To provide information about marketing experience of the improved quality cardamom, obtained using the gasifier system, and about the premium it could fetch.

The owner of the *bhatti* agrees to use the gasifier system in as many batches as possible (at least 5 batches) during the harvesting season producing half ton or more of improved quality cardamom. In case the owner of the *bhatti* fails to use the gasifier system for any reason for agreed number of batches, then TERI will have a right to take back the system from the site.

3.3 Fabrication of Mark-2 pilot plant units in Sikkim

Since very little time was left for starting of cardamom harvesting season in Sikkim, M/s Figu Engineering Works, Ranipool (who fabricated the gasifier system for earlier field testing) was given the job of fabrication. One model was fabricated under the supervision of TERI's technicians, during which the fabricator gained enough experience and fabricated the remaining systems on his own.

Since a large number of systems had to be fabricated, a store room was hired in front of the fabrication shop in Ranipool which was used for casting of more than 35 insulation rings, storing them along with other system components like oil barrels, grate, MS connecting piece, top cover, flame arresting sheet stand etc. Figure 3.1 shows the watering of insulation rings in store room for curing while Figure 3.2 shows the view of the store room where all system components were stored after fabrication. Figures 3.3 - 3.5 show the mass production of various system components in progress at M/s Figu Engineering Works, Ranipool. One lot of 8 units was transported to North Sikkim on 1st October so as to start the field testing work at sites where the harvesting was supposed to start in the 1st week of October, followed by a second lot of the remaining systems after two weeks (See Figure 3.6).

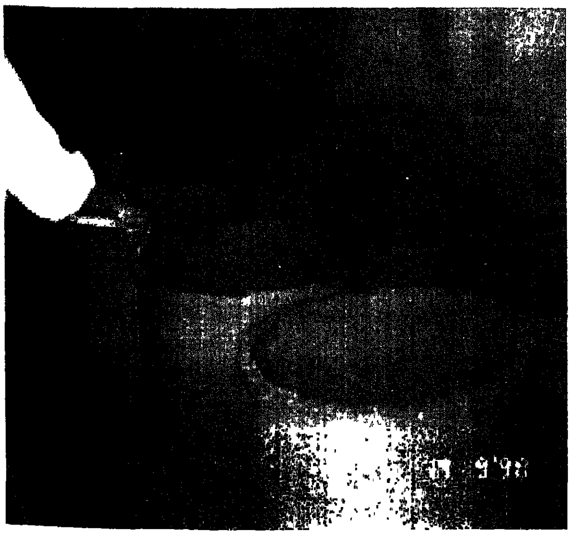


Figure 3.1. Watering of insulation rings in the store room for curing

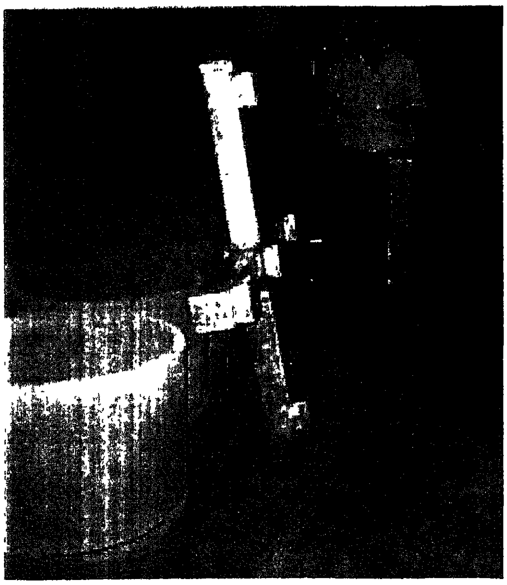
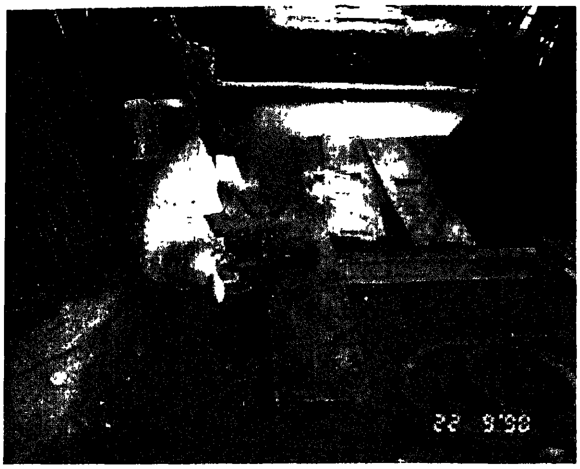


Figure 3.2. Gasifier system components stored in a store room at Ranipool



igure 3.3. Fabrication of gasifier system omponents: MS connecting piece

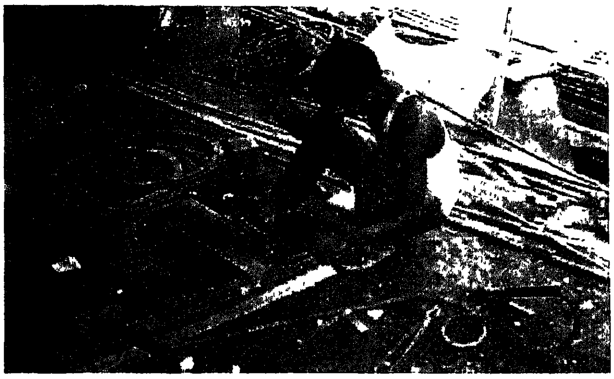


Figure 3.4. Fabrication of gasifier system components: MS grate

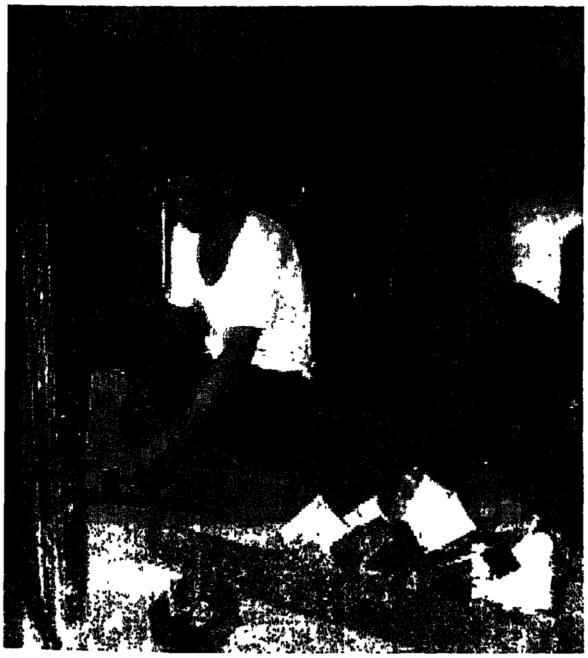


Figure 3.5. Fabrication of producer gas multiple burner components

Figure 3.6. Mark-2 gasifier system pilot plant units transported to Mangan (north Sikkim)

The complete set of the gasifier system consisted of the following components:

Bottom barrel/gasifier (modified used oil barrel, one side open)
Top barrel/extended hopper (modified used oil barrel, both side open)
MS Grate
Two castable insulating rings
MS cylinder (with dampers) connecting both barrels
Gasifier top with water seal groove
Gasifier top cover with handle
GI sheet chimney/flaring duct
GI sheet duct connecting gasifier and burner
GI sheet producer gas burner
Burner port plates
Gas duct end plugs
Burner shield
Perforated MS sheet as flare arrester.
MS stand for holding flare arrester
Grate shaker rod
Flaring torch rods

CHAPTER 4

Field testing of Mark-2 units in pilot scale phase

4.1 System upgradation of Mark-1 units field tested in 1997

In the project review workshop of Action Research Phase it was decided to provide assistance to the farmers who field tested the Mark-1 units in the cardamom harvesting season of 1997. In order to get feedback from the farmers about any help needed in rectifying/maintaining the present system, all the farmers were contacted personally either by TERI staff or by Mr Bhutia. After several trials Mr Rai could be contacted at Assam Lingzey, but he had already harvested the cardamom in his traditional *bhatti* due to some misunderstanding in communication.

The other four farmers contacted informed that they will be operating the system during this year's harvesting season also. After coming to know about further improvement in the system design, the farmers expressed their wish to get their systems upgraded. Therefore it was decided to get the additional components required for converting the system to the double barrel system with water seal fabricated. These system components were then supplied to them so as to enable them to operate the improved system with more ease and convenience at par with the farmers selected for field testing during pilot scale phase.

4.2 Training on installation and operation of the system

Earlier it was planned to provide centralized training to all the selected farmers at the time of installation of the first pilot scale plant in Mangan. But due to distant locations and staggered harvesting time for individual farmers, instead of doing centralized training at one site farmers/operators at each selected field testing sites were trained by TERI team during the first batch of drying at respective site.

Video shooting was taken during installation of the first Mark-2 pilot plant unit at Thingchim using a handycam in which efforts were made to explain step-by-step procedure of installation of Mark-2 gasifier system in existing *bhatti*. Similarly video shooting was done during the first batch of operation at the unit installed at Ravang Khola where procedure for start-up and regular gasifier operation was shown. This video clipping (of about 40 minutes duration) in its raw form was shown on the local cable TV network at Mangan to create awareness of the technology among the local population and to give some brief background to selected farmers before actually installing the system in their *bhattis*.

Training was planned for the field staff of the Horticulture Department from all the districts of Sikkim during the first half of November. But even after a lot of persuasion, this could not materialize during the cardamom harvesting season of 1998 in the pilot scale phase.

4.3 Field performance monitoring of the system

In all fifteen Mark-2 systems were fabricated and four Mark-1 systems were upgraded which were field tested in the 1997 cardamom harvesting season. But due to very low yield of the cardamom in their fields Mr I B Gurung (Kaluk, West Sikkim) and Mr Ongay Topden (Ravangala, South Sikkim) could not operate the system even though they made arrangement of dry cut wood well in advance this year. Mr Gurung had constructed a new improved *bhatti* so as to accommodate gasifier system as per the suggestions of TERI staff. Mr P G Tensing, like last year used the gasifier system for maximum number of batches system in his Pentok *bhatti*.

Due to untimely rains during flowering stage of cardamom, the average yield of large-cardamom in Sikkim was very low (50-90% lower compared to the last years yield). This was more pronounced in upper elevations. Since the project activity started very late the gasifier systems were got fabricated at Ranipool and the first lot of eight gasifier systems could be transported to Mangan only in the first week of October. By that time the cardamom harvesting was completed in the lower and middle elevation. Due to this unpredicted low yields the number of batches dried in the gasifier system were also lower than those planned. After taking the system, some farmers could not operate it due to very low yield in their field. Others operated it for less number of batches. Figures 4.1-4.5 show the photographs of few pilot gasifier units in operation in the field during the harvesting season of 1998. Photographs in Figures 4.6-4.8 shows field visits of officials to see the field testing of gasifier pilot units in Mangan.

4.3.1 Details of the pilot - field testing sites

Mr Karma Zongtenpa, Mangan

Gasifier system was installed in the field near Mangan Sadar Hospital. This site was in the lower area and cardamom harvesting was over in September. The farmer brought cardamom from Manul farm and used the gasifier for five batches. In all 1050 kg raw capsules were dried using gasifier system with specific fuel consumption range of 0.65 to 0.95 kg wood per kg raw capsule. Due to use of wet wood in the first batch it took almost 26 hours to dry cardamom. Later on the farmer was convinced that dry wood gives problem-free smooth operation and consumes very less wood. In one batch drying was over within 15 hours only. The quality of cardamom dried was very good. The farmer could fetch high premium of the order of Rs 10-15 per kg in the local Mangan market.

per kg in the local Mangan market.

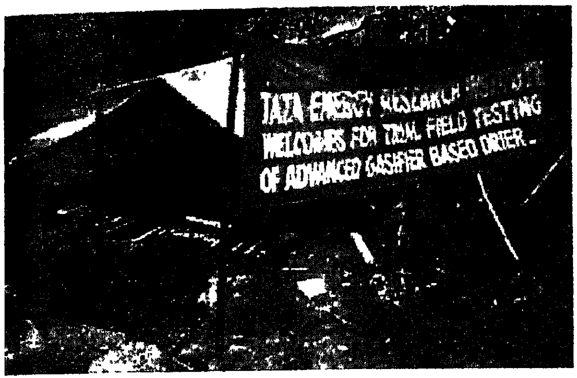

TATA ENERGY RESEARCH
WELCOMES FOR TRIAL FIELD TESTING
OF ADVANCED GASIFIER BASED DRIER.

Figure 4.1. Mark-2 gasifier system installed near Sadar Hospital in Mangan

Figure 4.2. Mark-2 gasifier system installed at pilot phase field testing site at Naga

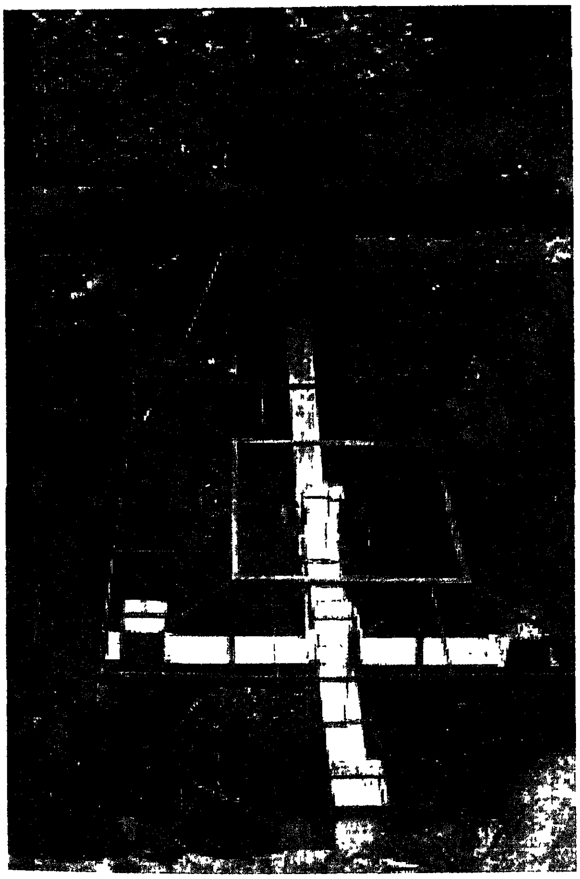


Figure 4.3. Aerial view of Mark-2 gasifier system installed at Ravang Khola

Figure 4.4. Mark-2 gasifier system installed at pilot scale field testing site at Dzongu

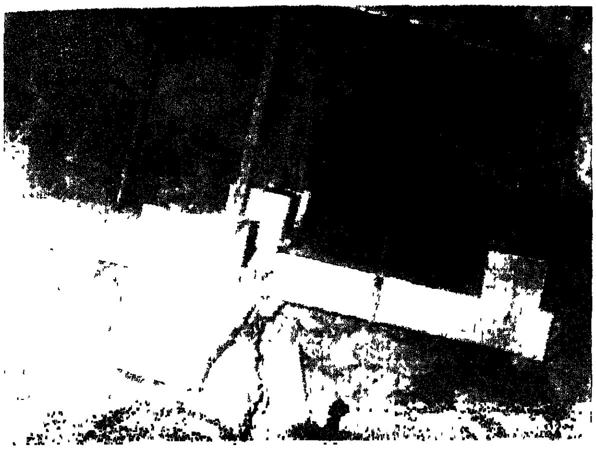


Figure 4.5. Multiple producer gas burner in operation during pilot plant field testing

Figure 4.6. Field visit of Dr Joseph, LO/ISPS to pilot scale plants installed in Mangan

Figure 4.7. Field visit of Horticulture Department officials to pilot scale plants in Mangan

Figure 4.8. Mr G K Gurung, Principal Director Horticulture, visits pilot scale plants

Mr Ugen Palzor, Ravang Khola

The farmer has two farms one at Ravang Khola and other at Manul. The unit was first installed at Ravang Khola. This was one of the first systems operated in the field and therefore video shooting showing procedure for startup of gasifier system, regular operation and some expected trouble shooting techniques was taken at this site. Only one batch of 410 kg could be dried here taking about 19 hours with specific fuel consumption of 0.85 kg per kg raw capsule. Later on the system was supposed to be shifted to Manul farm where main cardamom plantation is located, but since owner went outside Sikkim on tour, it was not done by his field staff.

Mr Thendup Ripon, Thingchim

This was the site where the first gasifier system at very high altitude (well above 5,000 ft elevation) was installed. Despite high altitude and steep narrow slippery roads all the system components could be transported easily on shoulders using ropes and bamboo basket through one hour walk through jungles.

The *bhatti* here was an old abandoned Spices Board flue pipe curing house which has a well constructed 8' × 10' room with wiremesh platform to load cardamom capsules. Since it was a well constructed room with cement walls and top ventilators it was decided to use it for installing the gasifier system for field testing. Video shooting was taken here using handycam to capture step-by-step procedure of installing Mark-2 gasifier system.

By the time gasifier system was installed all the cardamom from lower range was already harvested. In all 1042 kg of raw capsules could be dried from the upper range area of the estate. Average specific fuel consumption was quite low (0.5-0.6 kg per kg raw capsule) due to the well constructed closed room as *bhatti* with batch drying time ranging from 19 to 22 hours. The colour of the dried capsule was very good and farmer could fetch premium of Rs 9-10 per kg easily in local market.

Mr Mark Tshering, Ravang Khola

The gasifier was installed near old Mangan market. As lower and middle elevation cardamom was already harvested, and yield in upper range was very low, only one batch of 150 kg raw capsule could be dried using gasifier system in 16 hours. The wood was wet and was not of good quality giving problem in smooth operation of gasifier.

Lakchung Bhutia, Thingchim

Here the gasifier system was installed at Thingchim by making a temporary *bhatti* structure using GI sheets. Farmer himself installed and operated the gasifier on his own. Only one batch of 400 kg raw capsule could be dried using gasifier system as lower range cardamom was already harvested in September and upper range yield was very low. The gasifier operation was very smooth due to good quality dry cut wood and it took only 18 hours to dry 400 kg raw capsules with specific fuel consumption of 0.55 kg per kg raw capsule.

Mr Zigmi Ongda

This was the farm located above Nampthang and Ambithang. Since cardamom in the lower belt was already harvested in September and yield was too low (by 80-90%) in the upper range only one batch of 680 kg raw cardamom could be dried here using gasifier system. As dry wood was not arranged by the farmer it has to be dried first and hence gasifier operation took lot of time.

Ms Karma Gyatsen, Naga

In this farm located at Naga, two batches of cardamom were dried with specific fuel consumption in the range of 0.8 to 1.2 kg per kg raw capsule. The traditional *bhatti* here is well constructed with cement + sand plastering on inner toper portion. Use of wet wood (complete dry wood was not arranged) was the reason for longer time and comparatively higher fuel consumption in spite of such a good traditional *bhatti*. The colour of the dry cardamom here was very good.

Ms Tashi Lhamo, Naga

Gasifier was installed at Mangan near fire office. In all, three batches could be dried here using gasifier system processing 1460 kg raw capsules. Drying time observed was 17-26 hours depending upon quantity of raw capsules loaded per batch with specific fuel consumption in the range of 0.53 to 0.84 kg per kg raw cardamom.

The farmer showed lot of interest in gasifier system operation and told that for next year's cardamom harvesting season sufficient quantity of dry cut wood will be arranged well in advance as this system consumes less fuelwood and quality of the dried cardamom is very good compared to traditionally cured cardamom. The farmer also expressed desire to construct an improved *bhatti* design as presented in the project review workshop and requested for necessary guidance to construct improved *bhatti* at the site.

Mr Topgay Kazi, Malling Mangan

This gasifier installation was at a higher altitude region of Mangan called Malling Mangan. Due to low yield in upper elevation only one batch could be dried using the gasifier system. About 600 kg raw cardamom could be dried in 26 hours with specific fuel consumption of 0.6 kg per kg raw cardamom capsules.

Mr Chhoden Lepcha, Dzongu

This farmer from upper Dzongu area showed interest in procuring and field testing gasifier system. Therefore Mr Pemza Tenzing's system was transferred to this farm. Later on Mr C T Kazy's system was given to Mr Pemza Tenzing but he did not use it as dry wood was not arranged. This gasifier field installation was also in a quite interior location and above 5000 ft elevation, situated at Pasingdang (Upper Dzongu) where system components had to be transported through a narrow steep walkway up the hill. Here also cardamom was already harvested before 2nd week of October in lower ranges. Due to low yield in upper ranges this year, two batches of cardamom (about 1150 kg raw capsules) could be dried in this *bhatti*. It took around 24-28 hours to dry cardamom consuming about 0.7 to 0.9 kg wood per kg raw capsule. The quality of cardamom dried was very good. The farmers in this area showed lot of interest and enthusiasm in gasifier system and more than five farmers showed willingness to procure system from the market if made available.

Mrs Chumsey Lepcha, Dzongu

As farmers from Dzongu area showed lot of interest in gasifier systems, this was another system site which was not selected earlier. Mr Sonam Dadul's system (since he showed inability to use gasifier system due to absence of dry wood and majority of cardamom in lower ranges was already harvested) was transfer to this site in upper Dzongu area. This field testing site was also located at very high altitude near Pasingdang in upper Dzongu area. Only one batch of 350 kg raw cardamom could be dried here due to low yield in upper range. Wet wood use gave operation problem requiring larger drying time (26 hours) and specific fuel consumption was on a higher side, viz. 1.1 kg per kg raw cardamom. Lot of interest was shown by farmer and surrounding population showed willingness in procuring gasifier systems. The opinion of the farmers here was that such a simple and transportable system is much useful for small farmers in interior areas. They appreciated quality improvement and said Rs 10-15 per kg premium is very much attractive for small farmers as their earning will increase substantially and proper drying of capsule will help them for long duration safe storage without fungus problem.

Mr P G Tenzing, Pentok Mangan

Gasifier system was installed at Pentok Mangan and cardamom was brought here from Manul and Malling fields. Last year's trained operators Mr Dawa and Mr Lal Bahadur operated the system very well. In all seven batches of drying using gasifier system was done processing 3145 kg raw capsule. In addition partially dried cardamom from flue pipe curing house installed near his field at Manul was also dried finally using gasifier system at Pentok. Smooth operation of gasifier due to dry wood gave low specific fuel consumption of the order of 0.53 to 0.65 kg wood per kg raw capsule. Dry cardamom quality was very good and the farmer is selling it in 1-2 kg pouches in the retail market of Sikkim and is also trying to sell it to tourists through hotels and restaurants in Sikkim at a price of Rs 200 per kg.

The owner (Mr P.G. Tenzing's mother) tried one batch in the Spices Board's flue pipe curing commissioned this year at Manul but it consumed almost all the dry wood stock arranged for drying the entire season's crop and took almost 9 days to dry cardamom. After this experience, the owner brought all the remaining cardamom from Manul to Pentok and dried it using the gasifier system. On 12 November one batch of cardamom from Pentok was taken to flue pipe curing house installed at Ambithang but later on it was also brought back to Pentok to complete its drying using the gasifier system.

The owner showed a lot of interest and requested for guidance in constructing an improved *bhatti* this year after seeing it during presentation of project review workshop.

Other farmers selected for pilot scale field testing did not use the system because of very low yield in upper ranges and as lower range cardamom was already harvested before gasifier installations. All the farmers, however, assured that since they have the system now in their possession, they will arrange for dry wood well in advance and will dry the cardamom in the gasifier system in the next cardamom harvesting season.

The summary of the performance monitoring data, giving quantity of raw cardamom processed, drying time required, and specific fuel consumption rates, of the pilot scale plants tested during the cardamom harvesting season of 1998 is given in Table 4.1.

Table 4.1. Details of field testing of gasifier system during harvesting season of 1998 in Mangan

Sr. No.	Name	Quantity dried (kg fresh) Drying time (hrs) SFC (kg/kg fresh)	Remarks
1	Mr Tenzing Dadul (Ex-MLA) Lingza, Upper Dzongu	---	Did not use the system after receiving it. Reason given harvesting over in lower areas, low yield in upper area
2	Mr P G Nangpa, Lingza, Upper Dzongu	---	Did not use the system after receiving it. Reason given harvesting over in lower areas, low yield in upper area
3	Mr Thendup Ripon, Thingchim	1242 kg 19-22 hrs 0.5-0.6 kg/kg	Low yield, but used system to dry all the cardamom harvested in upper area
4	Mr Pemza Tenzing, Thirung, above Malling (his system was later given to Ms Chhoden Lepcha, Dzongu)	1150 kg 24-26 hrs 0.7-0.9 kg/kg	
5	Mr Zigmi Lachenpa, Salim Pakyal, Dzongu	---	Didn't use the system after receiving it. Reason given low yield and unavailability of wood.
6	Mr Zigmi Ongda, Kaluy, above Nampthang, Ambithang	680 kg 38 hrs 0.84 kg/kg	Low yield; used the system Used wet wood
7	Mr Karma Zongtenpa, Mangan	2050 kg 15-26 hrs 0.65-0.95 kg/kg	Installed the system in Mangan and brought the capsules from Manul field
8	Mr Mark Tshering, Ravang khola	150 kg 16 hrs 1.3 kg/kg	Very low yield this year
9	Mr Ugen Palzor, Ravang Khola	410 kg 19 hrs 0.85 kg/kg	Used system in Ravang Khola unit and did not transfer it to Manul as he went to Himachal and personnels in the field didn't use it in his absence due to unknown reasons.
10	Mr Topgay Kazi, Malling Mangan	600 kg 26 hrs 0.6 kg/kg	Low yield.
11	Mr Pentook Kazi, Lantay Khola, Manul Mangan	---	Didn't use the system after receiving it. Reason given low yield and unavailability of wood.
12	Mr Sonam Dadul, 12th mile Dzongu (This system was later given to Ms Chumsey Lepcha, Dzongu)	350 kg 26 hr 1.1 kg/kg	Very low yield, wet wood
13	Ms Tashi Lhamo, Naga	1460 kg 17-26 hrs 0.53-0.84 kg/kg	
14	Mr Karma Gyatsen, Naga	750 kg 20-30 hrs 0.8-1.2 kg/kg	

Sr. No.	Name	Quantity dried (kg fresh) Drying time (hrs) SFC (kg/kg fresh)	Remarks
15	Mr Lakchung Bhutia, Thingchim	400 kg 18 hrs 0.55 kg/kg	Brought only one batch capsule from very high altitude field to home
16	Mr C T Kazi, Above Malling (Mr Pemza Tenzing later took this system and installed)	---	Later on Mr Pemza Tenzing, AILCGA President, took this system and installed in upper field, but didn't use it. Reason may be unavailability of dry wood.
17	Mr P G Tenzing, Pentok Mangan	3145 kg + partially dried cardamom from flue pipe curing system 23-28 hrs 0.53-0.65 kg/kg	Mr P G Tenzing's mother tried one batch in flue pipe system at Manul but once it took almost 9 days to dry. She dried all remaining batches in Pentok gasifier system after carrying it from the nearby field to Pentok. On 12th November one of the batch was loaded in Ambithang Flue pipe system but later on it was also brought to Pentok to dry it using gasifier system

4.3.2 Monitoring of cardamom quality dried in pilot scale plants

In order to check and monitor the quality of the cardamom dried using gasifier system during the pilot scale phase, small quantity of samples were collected randomly from farmers during the field testing of Mark-2 gasifier system. These samples were then analyzed in the laboratory at TERI's Gual Pahari campus for two major quality parameters of cardamom viz. volatile oil content and moisture content. Experimental set up and procedure was followed as per the Indian standards IS 1797-1985 similar to earlier quality analysis done during Action Research Phase[2].

The summary of the quality analysis data of large-cardamom obtained using Mark-2 gasifier system field testing during pilot scale phase is given in Table 4.2.

From the data given in Table 4.2, it can be seen that the cardamom dried using gasifier system gave consistently higher volatile oil content in the range of 2.2-2.7% (ml/100 gm). This confirms the findings of the Action Research Phase that gasifier system helps in retaining more (over 35%) volatile oil in dry cardamom due to controlled burning of producer gas.

For majority of the samples the moisture content of cardamom dried was within acceptable limit of 10% (w.b.). However, a few samples show higher moisture content levels indicating incomplete drying by the farmers.

Table 4.2. Summary of the quality analysis data of large-cardamom

Sample No	Volatile oil content (ml/100 gm)	Moisture content (% w.b.)	Sample No	Volatile oil content (ml/100 gm)	Moisture content (% w.b.)
Mr Thendup Ripon, Thingchim					
1	2.42	11.2	3	2.51	8.6
2	2.38	9.3			
Mr Karma Zongtenpa, Mangan					
1	2.47	10.2	3	2.41	7.9
2	2.31	9.3	4	2.37	8.4
Mr Ugen Palzor, Ravang Khola					
1	2.39	8.9	3	2.41	9.8
2	2.45	10.1			
Ms Tashi Lhamo, Naga					
1	2.50	11.61	4	2.70	9.1
2	2.49	10.2	5	2.56	8.5
3	2.53	8.9			
Mr P G Tenzing, Pentok Mangan					
1	2.44	8.8	3	2.52	13.1
2	2.37	9.3	4	2.45	9.6
Ms Chumsey Lepcha, D'Zongu					
1	2.30	7.9	4	2.45	8.8
2	2.39	10.2	5	2.36	9.3
3	2.32	8.6			

The overall quality of the cardamom dried using the gasifier system was very good which was appreciated by the farmers due to visual appearance of the cardamom due to its natural reddish colour and dryness. This was confirmed by the fact that farmers could sell the produce at premium (Rs 10-15 per kg) price in the local market due to its better appearance and uniform, complete dryness.

CHAPTER 5

Study on large-cardamom oil

Successful development and field testing of the gasifier system during the action research phase proved that there is a definite improvement in quality (both appearance and volatile oil content) of the large-cardamom obtained using the system. Trial test marketing of the improved quality product gave encouraging results, indicating scope for fetching around 10-15% premium price in the market. During discussions with the traders, it was felt that since the volatile oil content is much higher (by about 35%) and that too without any burnt smell, extracting and marketing large-cardamom oil can now become an economically viable option. Presently small-cardamom oil from south India is being marketed for use as flavouring agent at a price of about Rs 12,000-13,000 per litre in domestic as well as international markets[2]. Therefore it was thought worthwhile to carry out some study on cardamom oil (both small and large) to review the work done so far on cardamom oil, its composition, possible applications of various constituents and comparison of small and-large- oil.

An extensive literature survey was made and discussions were carried out with various industries who are utilizing cardamom oil at present, and with institutions working on cardamom oil analysis, etc. Assistance was sought from M/s Shambhavi Agency who are marketing a newly launched product called Spice Drop (which is an extract of various spices such as small-cardamom, ginger, chilly etc.) as replacement of whole spices in northern India. The findings of the study are summarized in the following sections.

5.1 Composition of seeds

Proximate analysis of large-cardamom seeds as available from the literature(1) indicate the presence of following major constituents[4]:

- Moisture : 8.5%
- Protein : 6%
- Volatile oil : 2.8%
- Crude fibre : 22%
- Starch : 43.2%
- Ether extract : 5.3%
- Alcohol extract : 7%
- Ash : 4%.

Seeds also contain 666.6 mg/100 g calcium, 412.5 mg/100 g magnesium, 61.0 mg/100 g phosphorus and 14.4 ppm fluoride. Other components of seeds include glycosides, Petunidin 3,5 diglucoside[5] ($C_{28}H_{33}O_{17}$, mp>300 °C) and Leucocyanidin 3-O-β-D-glucopyranoside($C_{21}H_{24}O_{12}$, mp 230 °C). A new aurone glycoside, Subulin ($C_{28}H_{32}O_{16}$, mp178 °C, 0.037%) is elucidated[6] as 6,3',4',5'-tetrahydroxy-4-methoxyaurone-6-O-α-L-rhamnopyranosyl-(1→4)-β-D-glucopyranoside. Acid hydrolysis of Subulin gave the aglycone subulaurone ($C_{16}H_{12}O_7$, mp 320 °C). The presence of a chalcone, cardamonin[7] ($C_{16}H_{14}O_4$, mp 207 °C),and a flavanone, alpinetin is also reported.

Ash content is said to be indicative of the cleanliness of the product. Starch content increases with the maturity level of the fruit but the most functionally important constituent, volatile oil, decreases a little with the maturity level, probably due to increase in starch content while the synthesis of oil has already reached the maximum level.

5.2 Chemical composition of volatile oil

Chemical composition of large-cardamom oil is being studied from a decade. Finnmore[8] in 1926 noted predominance of 1,8 cineole in large-cardamom oil. Nigam and Purohit[9] explored the oil in detail. The coarse ground seeds on steam distillation yielded 2.5% of dark yellow oil which was resolved into fractions by distillation. The ingredients were identified as Sabinene-6.6%, terpinene-10.7%, terpineol-7.2%, terpinyl acetate-5.1%, and bisaboline-3.6%. In 1969, Lawrence[10] contributed to the field by analyzing pale yellow oil by gas chromatography using Carbowax 20M column. From this study cardamom oil is known as exceptional to contain δ-terpineol as a constituent. Patra et al.[11] recently spotted β-terpineol as a constituent of cardamom oil. Balakrishnan et al.[12] used two sets of columns in gas chromatography viz. Carbowax 20M and FFAP 10% on chromosorb WAW, 6-80 mesh and identified new components in oil viz. camphene, linalool, geraniol and neryl acetate. Table 5.1 gives composition of volatile oil of large-cardamom summarizing the constituents detected by various scientists so far. Continued detection of new compounds in the oil by researchers shows possibility of a few more hidden compounds in the oil.

The oil extracted from cardamom cured in traditional *bhatti* system is supposed to be of inferior quality mainly due to presence of smoky odour to oil on its extraction. Quality improvement using gasifier system for drying may not only increase its content but may facilitate the detection of newer constituents. Thus there is a need to study the composition of gasifier dried cardamom oil in detail.

Table 5.1. Constituents in the oil of large-cardamom

Constituents	Percentage as reported by various scientist			
	Nigam & Purohit	Lawrence	Patra et al.	Balakrishnan et al.
Myrcene	-	0.3	-	0.43
α-Pinene	-	2.0	-	3.11
β-Pinene	-	2.4	-	3.67
Sabinene	6.6	0.2	9.1	1.45
Camphene	-	-	-	0.44
α-Terpinene	10.7	0.2	-	-
γ-terpinene	-	0.2	16.2	0.58
Limonene	-	10.3	-	6.38
p-Cymene	-	0.2	-	0.3
1,8 cineole	64.9	74.0	63.3	75.27
Linalool	-	-	-	0.14
Geraniol	-	-	-	0.12
α-Terpineol	7.2	5.6	4.9	5.3
β-Terpineol	-	-	0.5	-
δ-Terpineol	-	0.8	-	-
4-Terpineol	-	2.0	-	1.42
Nerolidol	-	1.0	-	0.12
Neryl acetate	-	-	-	0.14
α-Terpinyl acetate	5.1	-	-	-
α-Bisabolene	3.6	-	1.3	-

In order to initiate the work in this area the team got a few samples of cardamom oil (both from traditional and gasifier system) analyzed for some of its major chemical constituents. The results of the analysis are summarized in Table 5.2. Though the oil composition may be comparable the organoleptic quality of volatile oil of large-cardamom obtained by drying using gasifier system will be better due to absence of smoky flavour/odour and there is need to carry out much more detailed analysis which can also determine purity of its chemical constituents and scope for its extraction for industrial use. At present there are no quantitative tests to decide the extent of smoky flavour in large-cardamom oil.

Table 5.2. Comparison of volatile oil of cardamom dried using traditional and gasifier system

Major constituent of volatile oil	Large-cardamom dried in	
	Traditionally *bhatti*	Gasifier dryer system
α-Pinene	2.84%-3.93%	3.00%-3.89%
β-Pinene	5.03%-9.00%	6.55%-7.93%
1,8 Cineole	78.40%-83.03%	76.53%-84.86%
4-Terpineol	0.42%-0.48%	0.09%-0.57%
α-Terpineol	4.55%-5.84%	4.01%-5.69%

5.3 Comparison between volatile oils of small and large-cardamom

Compared to the true cardamom or small-cardamom volatile oil, large-cardamom oil varies in composition. being high in monoterpene hydrocarbons, average to very high 1,8-cineole. and fairly high terpenic alcohols. Table 5.3 shows the presence of all major components of small-cardamom oil in the large-cardamom oil also, although the quantity of these may differ. Small-cardamom oil also has some more hydrocarbons, acids, alcohols, phenols and cabonyls other than these compounds but in trace amounts. An earlier analysis of the volatiles of *Amomum subulatum* had shown higher contents of the hydrocarbons[9] sabinene (6.6%) and γ-terpinene (10.7%), besides the sesquiterpene bisabolene (3.6%) and some terpinyl acetate (5.1%). However, these have not been confirmed by later gas chromatographic analysis[10, 11, 12]. Since these compounds are not reported in later analysis this suggests that the quality of large-cardamom, and the method of oil extraction process probably affects the quality of oil in terms of its ingredients. If the quality of large-cardamom is given some consideration for its improvement, it may result in the production of a better quality of volatile oil which can be used as a substitute to true cardamom oil, at least partially, as all important components needed for flavouring and other purposes are present in large-cardamom oil also.

5.4 Importance of various constituents of large-cardamom oil

In order to assess the possibility of exploitation of large-cardmom oil for industrial use either for flavouring or for medicinal purposes, it is essential to get information on the characteristics of various constituents present in large-cardamom volatile oil. Through an extensive literature survey and internet search, this information on characteristics of various constituents present alongwith its effects for use as flavouring agents and medicinal description, was gatherred. The information collected is summarised in Table 5.4.

Table 5.3. Comparison of the oil composition from small and large-cardamom[13]

Constituent	Small-cardamom (*Elletaria cardamomum*)	Large-cardamom (*Amomum subulatum*)
Myrcene	0.37-2.5	0.5-11.13
α-Pinene	1.10-13.0	2.0-3.11
β-Pinene	0.2-4.9	2.4-3.67
Sabinene	2.5-4.9	0.2-9.10
Camphene	0.02-0.13	0.44
γ-Terpinene	0.04-11.2	0.2-16.2
D-Limonene	0.12-2.1	6.38-10.3
p-Cymene	0.4-0.7	0.2-0.3
1,8-Cineole	23.4-51.3	63.3-75.27
Linalool	2.1-4.5	0.14
Geraniol	0.25-0.38	0.12
α-Terpineol	0.8-1.9	4.9-7.2
Terpinen-4-o	0.14-15.3	1.4-2.0
Nerolidol	0.23-1.6	0.12-1.0
Nerlacetate	0.02-0.09	0.14
Terpinyl acetate	34.6-52.5	5.10
α-Bisabolene	0.07-0.83	1.3-3.6
β -Terpineol	0.7-2.10	0.8

5.5 Usage of large-cardamom[16]

The use of large-cardamom can be categorized as direct use of capsules and industrial use of its byproduct.

5.5.1 Direct usage of large-cardamom

Large-cardamom is used directly in the preparation of pickles, pulao, meat, vegetable curries and bettle leaves, where appearance of the cardamom is of importance and it needs some time to develop its aroma.

Table 5.4. Characteristics of various constituents of large-cardamom oil[14, 15]

Components	Flavor description	Effect for use as flavoring agent	Medicinal description
1,8-cineole	Fresh, camphoraceous, cool odor and taste, very diffusive and poor tenacity	Refreshing effect and lift, extensively used in perfume and flavors	Pharmaceutic aid of cough
Limonene	-	used in fragrance and perfumes	Antibacterial, antifungal, antiacne, septic shock treatment, anti cancer, etc.
α-terpineol	Delicately floral, sweet, lilac like	Citrus and spice compositions	used as antiseptic
β-Pinene	-	intermediate to perfumes and flavoring	substitute to α-Pinene
α-Pinene	perfume base	manufacture of camphor and synthetic pine oil	As insecticide
β-cymene	-	-	Antihistaminic and antifungal
4-Terpineol	Warm peppery woody with earthy, musty notes, pleasantly green	Mainly used in citrus and spice compositions warm, herbaceous effect	Respiratory tract disorders and disinfectant
Myrcene	-	Intermediate to manufacture of perfume chemicals	-
α-Terpinene	fresh lemonish	used for synthetic lemon flavor	-
Nerolidol	Woody, floral, slightly green	excellent tenacity	-

It is an important constituent of the *Garam Masala*, a spice mixture used with many meat and vegetable dishes and all spicy and rustic dishes. Cardamom is used at a 15% level with other spices such as cumin, fennel, cloves, cinnamon, mace, nutmeg, and saffron. It is also used in another combination at 25% with pungent spices such as ginger, pepper, garlic, cumin, cloves, coriander and tumeric. It is also used as a masticatory along with the traditional "pan" chewed after meals for freshening the mouth. In south India, large-cardamom is used in the preparation of snuff and *agarbattis*.

Large-cardamom is also used as a cheap substitute and extender for true or small-cardamom for flavouring sweet dishes. In European countries, the small amounts imported are essentially used to extend the costlier true cardamom in baked foods and in the Arab countries, to spice their beverages.

5.5.2 Industrial usage of large-cardamom oil

Cardamom oil has an advantage over whole cardamom except in those applications where the appearance of the cardamom is of importance e.g vegetable pulao, pickle, etc. In addition to the benefits and convenience it gives hygiene to the product. It also helps in giving consistency of flavour and aroma. Thus it has a big potential as a new product to both food products and medications, as well as non-food products.

5.5.3 Potential usage in food industry

Processed meat industry:

Dry sausages and pickled meat use cardamom and coriander as a typical seasoning mix. The move to the oil has accelerated by the increasing size of the manufacturing plants as it benefits production quality as well as ease of handling and cost savings.

Fish and vegetables:

Seasoning mixed for both fish and vegetables contain a wide range of spices. The use of oil will provide a means of easier preparation, reduced handling and costs.

Cheeses and dairy products:

The use of spices in cheeses is established in Germany. Spices are unlikely to be used in these products as the spices provide the flavoring plus visual impact. However spice oils will have significance in processed cheeses and savory spreads.

Baked goods:

In European countries, small amounts of cardamom are imported and essentially used to extend the costlier true cardamom in baked foods. The use of these in baked goods is traditional in Scandinavia and Germany. The move from the spice to their oil and oleoresin has been effectively taking place for many years because of ease in handling and simplicity in manufacture. It is used mainly in cake fillings, biscuits and snack products.

Soups, sauces, chutneys and dressings:

The increasing demand for convenience products available in the form of a dry mix for ready reconstitution has caused a rapid move from conventional seasoning towards dispersed or encapsulated oleoresins and oils.

5.5.4 Potential usage in non-food industry

Cosmetics:

The growing preference for herbal, spicy and spicy coniferous notes in products like shampoos and hair tonics are noted. Yet such extracts as those of cardamom are little heard of. The use of lesser known spice extracts can provide new product appeal.

Perfumes:

Perfumery uses a wide range of essential oils and oleoresins from sources far and wide. Thus it is an industry which can be targeted in India and could provide a new basis of product appeal.

Hygiene products:

Products like toothpaste, mouthwashes, etc. depends on essential oil to provide their pleasing flavor and making them not only acceptable but pleasant to use. The medicinal value of cardamom oil adds to the cleaning property by preventing many diseases in addition to cleansing action.

5.5.5 Medicinal usage of the oil

Large-cardamom is used as diuretic in case of gravel of kidney. It is used in digestive disorders which are marked by scanty and viscid secretion of intestine, as cure it promotes elimination of bile[17]. In a drug permeation study[18] of crude extracts of drugs, invivo and invitro, with rabbit skin as model membrane, the acetone extract of large-cardamom had the best effect in enhancing the penetration of indomethanin. The oil has an antifungal effect for keratinophilic fungi[19] proving its usage for treatment of cutaneous infections. Cardamom essential oil components also subside the post-operative side effects[20].

Collectively it can be said that it is used for halitosis, flatulence, hyperacidity, vomiting, diarrhea, dysentery, skin diseases, wounds, ulcer, neuralgia, cardiac, odontalgia, cephalalgia, liver congestion, splenomegaly, cough, bronchitis, fever, hyperdipsia, gonorrhea etc. [17].

The major component, 1,8 cineole, has its importance being an ingredient of most of cough syrups. Antiseptic value of α-terpineol has its own importance. β-cymene has antihistaminic and antifungal nature thus seems to be responsible for the cardamom oil usage for cutaneous fungal treatment as mentioned above. 4-Terpineol and δ-terpineol have effects on respiratory tract disorders and have a nature of disinfectant.

5.6 Trial test marketing of large-cardamom oil

In order to get the feedback of the business and industrial community on the volatile oil extracted from improved quality large-cardamom obtained by drying using TERI's gasifier system, several industries, traders, dealers, and institutes were contacted. A one page pamphlet (attached as Annexure 1) was prepared giving information of traditional as well as gasifier system of drying large-cardamom and advantages of gasifier system over traditional *bhatti* system. Quality improvement results of the laboratory experiments and possible impact on quality of volatile oil as well as possible potential of large-cardamom oil was highlighted. This pamphlet was sent along with a covering letter, requesting their feedback. Since limited quantity of extracted oil (obtained during laboratory testing of improved quality large-cardamom) was available at that time, a small quantity of oil sample was also sent to a few selected industries/traders to get their opinion on improved quality of oil. The list of personnel and organizations contacted can be classified into the following categories. (Annexure 2)

- Essence, flavouring agent suppliers
- Ayurvedic medicines
- Food products
- Menthol and peppermint products
- Perfumes, cosmetics and toiletries manufacturers and dealers

The response to the request of feedback/comments on improved quality cardamom oil was very low but still useful. It revealed that already many small sale flavouring, food product industries use volatile oil of large-cardamom oil as a cheap substitute for additon to the so called true or small-cardamom volatile oil. Therefore the general opinion was that it would enhance the use of improved quality large-cardamom oil if smoky odour is absent.

Some dealers like M/s Mittal Aroma Essential Oil Pvt. Ltd. said that they would like to have more quantity of oil sample which they can float in the market on a trial basis, and based on the feedback they can decide whether to get into the marketing of improved quality large-cardamom oil.

M/s Kanta Chemicals Co. who are manufacturers of perfume components told that they usually distill oil of small-cardamom. Only once they tried distillation of large-cardamom oil but could not use it out successfully in their product line due to presence of smoky flavour in traditionally cured large-cardamom oil. They showed interest in knowing the chemical

composition and analysis of improved quality oil and based on it will decide possible potential of it in their product line which is mainly perfumery products like *attars*.

M/s Fab Flavours and Fragrance (P) Ltd, Chandigarh informed that they buy the large-cardamom oil from south through agents in Haryana to use them as cheap substitute to small-cardamom oil in their products which are mainly food products like bakery items, ice cream essence, etc. When asked which parameters which they normally check for quality of oil it was told that trial use in small batch is the normal practice used by small scale industries. They showed interest in trying out improved quality large-cardamom oil if supplied in sufficient quantities. They are in the process of installing a gas chromatograph in their laboratory which is expected to be commissioned in a few months time where the oil can be tested for its constituents.

The general opinion regarding marketability of the improved quality oil was favourable, but a detailed chemical analysis for its chemical composition to prove its superiority and usability for a variety of applications is necessary. This would need extensive laboratory experimentation involving basic research and analysis. But it seems definite that the improved quality oil will have much more prospects and potential for its use than traditionally cured large-cardamom not only as cheaper substitute for small-cardamom but also for other new applications.

CHAPTER 6

Project review workshop

A one day project review workshop was organized at Hotel Chumbi Residency, Gangtok on 27 April 1999. The main objectives of this workshop were (a) to review the design improvement in the gasifier system based on comments/feedbackreceived by farmers and participants during last year's project review workshop under the Action Research Phase of the project, (b) to review and discuss the experience by the farmers during pilot scale phase in which more than 15 systems were installed in Mangan region of north Sikkim, and (c) to plan activities for popularization of the system in future. Another objective was to elicit comments/feedback from the concerned officials from state and central government departments, farmers, marketing experts etc. on system design and performance in the field. This was necessary so as to assess the success of the project and to take a decision whether to go ahead with the next phase of the project i.e. popularization of the gasifier system for drying of large-cardamom in Sikkim during the next year's cardamom harvesting season.

The participants of the workshop included officials from ISPS (Indo-Swiss Project Sikkim), Department of Agriculture, Horticulture, Industries, Planning and development, Government of Sikkim, Spices Board, DST (Department of Science and Technology), AILCGA (All India Large-Cardamom Grower's Association), cardamom farmers selected for field testing, District Industries Centre, cardamom traders, TERI (Tata Energy Research Institute), G.B. Pant Institute, and Marketing Consultants. Representatives of financial institutes like NABARD (National Bank for Agriculture and Rural Development), SIMFED (Sikkim Marketing Federation) and SBI (State Bank of India) also attended the workshop. The list of participants is given in Annexure 3.

Dr P J Joseph (LO/ISPS) welcomed all the participants of the workshop, specially farmers who came to Gangtok from north Sikkim to participate in the workshop despite bad road conditions, and gave information about activities initiated by ISPS under this programme of development of energy efficient system for drying large-cardamom. After giving a brief account of activities under cardamom drying project for the last couple of years he informed the participants that now the product development phase is coming to an end with the development of user-friendly and acceptable product by TERI. He asked all the participants to critically review the progress made by TERI in developing the system design which may be appropriate and suitable for conditions prevailing in Sikkim and said that the main purpose of this workshop

is to decide the strategy on how to take further steps in the direction of commercialization of the product developed so as to achieve wider penetration of the system in the field. Preferably the promotional model should be self-sustainable with minimal governmental support such as subsidy schemes.

In his Presidential and Inaugural address, Mr S W Tenzing (Additional Chief Secretary), expressed danger of survival of cardamom due to increasing severity of deforestation and destabilisation of ecological balance of the state. He felt that Spices Board is doing lot of work in Sikkim but more stress is on improving the productivity of the cardamom plantation to increase the production. He said that not much attention is being given on post harvest technology of cardamom and in order to improve the quality of dried cardamom to enhance export. He congratulated ISPS for taking initiative in this endeavour and for taking the right decision of assigning TERI, one of the largest energy institution in the world, the task of developing an energy efficient dryer. He appreciated the participatory approach adopted by ISPS in this programme. He said that TERI has done a good job by improvising the design further based on the feedback received during last year's field testing and arrived at a more user-friendly, affordable product and expressed hope that it would be acceptable to the farmers. He also expressed hope that this new development, considering the fact that the system results in improved quality produce and volatile oil, may revolutionize large-cardamom business in Sikkim by exploiting and popularizing industrial use of large-cardamom oil.

Dr Kishore (Senior Fellow, TERI) in his brief presentation stressed the fact that it takes a lot of time and untiring efforts before any concept gets developed and translated into a real commercial product. It is much more difficult if the new product being developed is to replace an age old traditional system or method. He elaborated on this further by taking a few case studies such as development of automobiles to replace horse-cart. He also gave examples of the efforts made by TERI under another SDC sponsored project for development of gasifier system for silk reeling industry and TERI's in-house programme of development of spherical fixed dome biogas plants. He said that it took more than ten years before TERI's biogas plant gained popularity in the absence of any outside financial assistance, but the time duration got shortened in case of silk reeling oven because of consistent support extended by SDC. He expressed satisfaction that due to the support extended by ISPS and more so by enthusiastic participation by farmers at the field level, TERI could develop a user-friendly and acceptable system design for drying large-cardamom in three years time. He said this could happen only due to extensive field testing to gain useful feedback from the users (farmers) which is essential for any successful

product development and said that it comes out slowly and in spurts and is proportional to time and efforts spent by researchers in the field.

At the end he hoped that the day long deliberations in this workshop will lead to a suitable programme for popularization of the gasifier system among the farmers of Sikkim. This, he said, would be possible only through close interaction and collaborative efforts by TERI (as technology developer), ISPS and Horticulture Department (as technology promotor) and user/farmers as technology adopters. He stressed the need to carry out further studies on large-cardamom oil extraction as possible value addition business for large-cardamom, as now the gasifier-based dryer yields more oil without burnt smell to it.

In his address, Mr H R Pradhan (Secretary/Horticulture) appreciated TERI's effort in developing an appropriate system design based on user feed back and hoped that it would be acceptable by them as it consumes less fuel, takes less time to dry and more importantly produces improved quality cardamom. He felt that the system looks economically attractive too seeing the feedback of test marketing of the improved quality cardamom obtained using gasifier system and that fact that even at Mangan farmers could get a premium of Rs 10-15 which should be quite attractive.

Presentation I: Development of improved gasifier system for curing of large-cardamom in Sikkim (Concept to pilot scale plants) by Mr Sanjay Mande (Fellow/TERI)

The theme of the first presentation made by Mr Mande was how, step by step, systematic R&D efforts helped TERI in the development of suitable gasifier system for drying large-cardamom from original idea/concept of using tandoor (starting point of development of low cost design) as an updraft gasifier into an acceptable Mark-2 pilot scale design of the system. The presentation gave description of year-wise R&D activities undertaken by TERI in the process of product development.

Study of traditional *bhatti* system (1995):

The major findings of the detailed study of traditional *bhatti* system of cardamom drying were:

- system operates with very low thermal efficiency of the order of 5-10%.
- excessive exposure to smoke due to wet wood burning results in smoky appearance.
- uncontrolled fire results in uneven drying, charring of capsules due to localized overheating, splitting of capsules and loss of volatile oil along with moisture.
- reaching of sparks from burning to the cardamom bed can cause loss due to fire hazards.

It was also realized that any R&D efforts in development of alternative dryer design should

- not call for large initial investment due to the low utilization factor (few batches per year)
- not use power for its operation in absence of electricity in most remote plantations
- try to utilize simple design with ease in its fabrication and operation
- try to maximize use of local material
- lead to quality improvement apart from fuel saving to enhance economic viability.

First year of Action Research Phase (1996-97)

The main objective of this year's R&D activities was proof of concept. Based on the finding of the earlier study and realizing the difficult situation in Sikkim for product development it was decided to try the tandoor (furnace using clay lining in low cost, used oil barrel) as a starting point of the development. He explained how the tandoor used for making rotis in northern India was developed into a low cost updraft wood gasifier (Mark-0) design which was field tested at Kabi in north Sikkim as proof of concept.

Field testing at Kabi proved the concept that use of gasifier to convert wood fuel into the more convenient gaseous form and then using the clean products of gas burning for supplying heat required for drying cardamom can result in improvement in quality and fuel efficiency. Field testing also stressed the need for changing system configuration (bringing gasifier outside the *bhatti* and burner inside) to have freedom in system component design and to allow use of larger wood size.

The major modifications made in the system design, based on feedback received, in order to arrive at Mark-1 design included:

- Finalization of system configuration (gasifier located outside *bhatti* and burner inside the *bhatti* below cardamom bed).
- Improved fuel charging system utilizing a simple lever mechanism.
- Optimization of square burner design for producer gas burning at design flow rates under natural draft mode.
- Use of pre-cast insulation rings instead of in-situ casting of insulation inside gasifier to reduce weight of individual system components for ease of transportation in hilly terrain.
- Successful trials with clay rings as insulating material.

Second year of Action Research Phase (1997-98)

In the cardamom harvesting season of 1997 the Mark-1 system design was field tested in all the four districts (Assam Lingzey in east, Kaluk in west, Ravangala in south and Mangan in north). The major achievements of the field testing are:

- improved thermal performance of the drying process; more than 60% fuel saving
- improved quality of dry cardamom: better appearance (retains natural reddish colour)
- retains more (>35%) volatile oil content in dried cardamom without burnt smell
- trial test marketing of improved quality cardamom received encouraging response from the market and during survey of more than 1000 households (end users) in Delhi indicated possibility of 10-15% premium on price.

Round the clock monitoring of the system in the field pointed scope for further improvisation in design in order to make it simpler to fabricate, easy to operate and therefore acceptable to the farmer. Major modifications made in the system design to arrive at Mark-2 design for pilot scale phase of the project included:

- use of water-seal door enabling quick fuel charging, eliminating gas leakage problem and simplifying fabrication of fuel charging system
- extended fuel storage hopper increased fuel charging duration from 1-2 to 6-8 hours
- development and use of multiple gas burner helped in providing uniform heat across the cardamom bed thereby reducing reshuffling requirements and more uniform drying.

Pilot Scale Phase (1998-99)

During the pilot scale phase of the project fifteen improved (Mark-2) prototype units were fabricated at a workshop in Ranipool and installed at the field testing sites selected around Mangan in north Sikkim. Salient features of the pilot scale phase are:

- mass production of the gasifier system in Sikkim after training of local fabricator
- operation of the farmers after training for first batch of operation
- premium of about Rs 10-15 received by farmers in Mangan market
- study on large-cardamom oil indicates scope for new business in large-cardamom through extraction of volatile oil.

A model improved design of *bhatti* suitable for gasifier system which further helps in improving the performance was developed and prototype unit was constructed at TERI's Gual Pahari campus for trial testing. This *bhatti* design can be multi-purpose: as a *bhatti* in cardamom harvesting season and as store room for rest of the time.

Selected transparencies, showing various stages of product development from concept to pilot scale plant, are given in Annexure 4.

Presentation II: Study on large-cardamom oil by Mr Sanjay Mande (Fellow/TERI)

This presentation was based on information gathered through literature survey and inputs given by M/s Shambhavi Agency (who are in the business of marketing Spice Drop: extracts of various spices). Through extensive field testing and quality analysis of the volatile oil it was proved that improved quality cardamom obtained using gasifier system gives more (>35%) volatile oil and does not give burnt smell to oil on extraction. This can open up a new era in large-cardamom business in Sikkim. Therefore the objective of carrying out study on large-cardamom and of this presentation was to stress importance of this probable new area of research. The presentation stressed importance of large-cardamom due to its characteristic aroma and medicinal value of oil. Various applications of large-cardamom seeds include preparation of various spices, medicinal powders, and that of its volatile oil includes as flavouring agent for food products, preparation of ayurvedic and unani medicines etc.

Due to low price even with present poor quality, large-cardamom is used as a low cost alternative to small-cardamom. Improvement in quality without burnt smell to oil by using gasifier can enlarge the scope of its use as an alternative to small-cardamom and can widen up the range of its applications.

The presentation gave detailed information on various aspects such as importance of each chemical constituent of large and small-cardamom oil as well its possible applications, previous data on quality comparison of small and large-cardamom oil as well as seed, techno-economic viability of cardamom oil extraction as an industry. Annexure 5 gives selected transparencies on cardamom oil study.

Important points/comments made by participants during discussions:

Mr I B Gurung, Kaluk, West Sikkim

During last year's field testing the new *bhatti* was constructed as per the design suggested by TERI staff. Gasifier system consumes less than 30% wood than that normally consumed in the traditional *bhatti* system. It requires low labour cost as less fuelwood is required and it is easy to monitor fire in gasifier system. The quality of the dry cardamom is very good and even after

several months there is no fungus attack which is otherwise common in traditionally cured cardamom.

Mr Pemza Tensing, Mangan, north Sikkim

He said that compared to last year the improved system design is quiet good and cost effective. According to him farmers appreciated TERI's R&D efforts involving lot of hard work and sincerity during field testing. He expressed concern that easy availability of completely dry wood in jungles where farmers do not stay near field is difficult. According to him it is not easy to remove the insulation rings on installation and it may require proper training to do so. He emphasized the need for coordinated marketing of improved quality cardamom in order to achieve higher premium price. According to him further reduction in price or some financial assistance scheme may help in popularizing the gasifier system among large-cardamom growers.

Mr Karma Yezor, HO, Mangan, north Sikkim

Though system is very good, improves quality of dry cardamom it is very difficult to arrange for dry cut-wood in jungles. He expressed fear of theft of dry firewood if one arranges and stores it well in advance.

Mr Jagnarayan Sharma, Figu Engineering Works, Ranipool, east Sikkim

In his opinion TERI's system design is quite simple and can be fabricated easily in workshops of Sikkim. He said that on his own he has visited the field testing sites in north Sikkim and felt that the system is easy to install and operate and TERI made lot of efforts in making the design so simple and easy. In reply to query about possible life of the system he said that if proper care is taken it should be much more than five years. In response to possible solution to corrosion problem he said aluminium can be used instead of GI but system cost may increase accordingly.

Mr Uchung Bhutia, SPO (Spices), Horticulture Department

According to him, if planned properly, making arrangement of dry wood and chopping it into required size is not a problem. He said that even after considering the limitation of the system that it needs dry cut wood it should get popularity among the farmers due to its several merits over traditional *bhatti* system viz. fuelwood saving, reduced drying time, and more importantly improved quality of dry cardamom which will fetch farmer more money for same quantity of cardamom produced.

In reply to farmers' worry about breaking of insulation rings during transport he said that if proper care is taken (carrying the insulation rings in bamboo baskets and not dropping it down suddenly) the rings are strong enough to withstand normal jerks and breaking rings during its transportation will not be problem. He said that traders are ready to pay Rs 10-15 per kg premium and that is the major indication of bright future of the system in Sikkim for drying large-cardamom. He suggested that system of organizing auction through Panchayat, inviting tenders could be explored for marketing of improved quality cardamom. He said that system developed by TERI requires low investment and can be used in existing *bhatti* too, and therefore is very much suitable for small farmers who are remotely located in cardamom fields.

Representative of Department of Science and Technology

He felt that there is need for larger demonstration phase consisting of 50-100 systems in one block. This is required to make farmers of the other three districts of Sikkim aware of the new system developed as done in north Sikkim during this year's pilot scale phase.

He said that CAPART has a scheme for financing credible NGOs upto 10 lacks for three years, but the NGO should be recognized and should be operating for at least three years. He said that AILCGA (All India Large-Cardamom Growers Association) can apply for financial assistance under this scheme for marketing improved quality cardamom or for promoting gasifier systems among cardamom growers. But General Secretary AILCGA said that though AILCGA is a registered body, it is in operation since last two years only.

GK Gurung, Director/Agriculture

He informed the workshop participant that Sikkim Government has already submitted a proposal for promotion of gasifier system for drying large-cardamom to Government of India and its approval is awaited which he expects will be received soon.

Concluding remarks

Dr Joseph said that the presentations by TERI professionals gave detailed description of the product development phase of the gasifier technology (action research phase and pilot scale phase) and its achievements, which give an encouraging picture. It seems that the gasifier system development work is now more or less complete and system is acceptable to farmers and indications are that improved quality cardamom will fetch better price in the market. He expressed the need for formulating a plan for widespread promotion of the system to make it popular among the farmers. He said that now onwards is a phase of technology transfer from

TERI to local staff which calls for a leading role from State Government with technical backup support from TERI staff. He thanked all the participants for their active participation in discussions and useful suggestions which will be useful while formulating the long term programme for technology promotion.

In his concluding remarks Director Horticulture Department said that the project review workshop was quite fruitful as lot of useful suggestions/comments came during the discussion due to active participation of all the participants. He expressed special thanks to all the farmers who gave their opinion about the system which they used in the field as it helped in critically reviewing the success of the system development work. He felt that still some very minor improvement may be needed in the system before it becomes a successful marketable product, but expressed the satisfaction over the present product design and its successful field performance. He said that a proposal is already submitted to central government and hoped that once it comes through, will help in wider demonstration of the system in various blocks. He emphasized the need for active involvement of field staff of the department in order to achieve successful technology transfer from TERI.

The workshop ended with vote of thanks by Dr Joseph.

CHAPTER 7

Conclusions

In the Action Research Phase of this project sponsored by ISPS, TERI had developed a Mark-1 gasifier system for drying large-cardamom and successfully field tested it at various sites in all the four districts of Sikkim. The response received during test marketing of improved quality cardamom in major trading centers of Delhi, Amritsar, Lucknow, Kanpur and Jaipur was quite encouraging. Everyone appreciated the better appearance and colour of cardamom dried using the gasifier-based system. It gave indication that if supplied regularly and with consistently better quality the cardamom dried in the gasifier-based system can fetch good premium, increasing income to the farmers. The survey of about 1020 households (end-users of cardamom) in Delhi also proved the acceptability of improved quality cardamom.

In the present pilot scale phase project, based on the feed back received during extended field testing and project review workshop of Action Research Phase, the system design was improvised further to make the system more easy to fabricate, operate and maintain. The major modifications made in the system to arrived at Mark-2 design are as follows:

- use of water seal for gasifier fuel charging door of the gasifier
    - stopped gas leakage from fuel charging door completely
    - made fuel charging process easy and quick
    - simplicity in fabrication due to absence of components like hinge, lever etc.
- development of double barrel gasifier design
    - extended fuel storage in gasifier for longer, continuous operation
    - reduced frequency of fuel charging from 1-2 hours to 6-8 hours
    - more stable burner operation due to consistently good gas quality for long duration
- optimization of multiple gas burner for operation with natural up-draft gasifier
    - more uniform distribution of heat across cardamom bed and hence more uniform drying

During the large-cardamom harvesting season of 1998 fifteen Mark-2 gasifier systems were installed in north Sikkim during pilot scale phase of the project. All the systems were made in the workshop at Ranipool in Sikkim after imparting training to the fabricator during fabrication of the first system. All the systems were installed by the farmers/field operators

under the supervision of the TERI staff. The systems were operated by the field staff successfully after getting trained under the guidance of TERI staff during the first batch of drying.

An improved *bhatti* design was developed and a prototype unit was successfully tested at TERI's Gual Pahari campus. It not only improves the performance of the drying process by minimizing heat losses but can also be used for other purposes viz. drying and storing of wet woodlogs, use as store room for rest of the year.

Analysis of random samples of cardamom collected during the pilot scale field testing confirmed the quality improvement in cardamom dried using gasifier system. The real proof of quality improvement and its acceptability in real cardamom trading business came from the fact that farmers who dried their cardamom using gasifier system during pilot scale phase could sell their produce at a premium of about Rs 10-15 per kg in the local market.

Study carried out on large-cardamom oil reveals that there are many valuable organic compounds (similar to small-cardamom) present in the volatile oil. Presently small-cardamom oil is used for flavouring purposes and is highly priced in domestic and international markets. Large-cardamom oil is sometimes used as cheap but inferior additive for small-cardamom oil. The absence of smoky flavour in cardamom dried using gasifier system will improve its organoleptic quality and can promote increased use of large-cardamom oil as an additive. There is a need to carry out detailed study on large-cardamom oil to determine composition of volatile oil obtained from improved quality cardamom for its potential applications and industrial uses.

In the project review workshop organized in April 1999, the Mark-2 gasifier system and its field performance during pilot scale phase was well appreciated. It was felt that the system design has now reached a stage which warrants promotion on a larger scale to popularize it among the cardamom growers of Sikkim. It was also felt that now there is a need for extensive training of the local staff of Horticulture Department, who will be finally doing the job of promotion of the system during the next cardamom harvesting season.

Once the demonstration and popularization of gasifier system in the field in all other districts of Sikkim is completed, the system can be promoted in a large scale through a proper marketing strategy and financial as well as technical back-up support.

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Annexure 1
Improving quality of large-cardamom and its oil (pamphlet)

mproving quality of large-cardamom and its oil

arge-cardamom drying in India

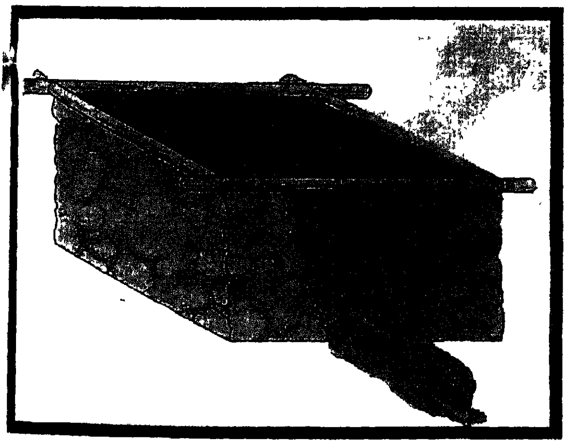
dia is the largest producer of large-cardamom in the world with 54% share, followed by Nepal (33%) and Bhutan (13%). rge-cardamom is a major cash crop of Sikkim with annual production of over 3500 MT from total cultivation area of 23,500 . More than 85% plantations are very small (with area < 2 ha) located in remote hilly areas. For its long duration storage d in order to bring out its aroma, cardamom capsules have to be dried to bring down its moisture content (from about 70-% (w.b.)) to below 10% (w.b.). Presently large-cardamom is dried using traditional *bhatti* system.

raditional *bhatti* system

raditional *bhatti* consists of 2 ft thick stone/rock wall tructure with large opening in front for burning wood gs. Large-cardamom is loaded in 10-12 inch thick bed n the wiremesh/bamboo mat platform. A primitive efficient (with operating efficiencies of the order of 5-%) smoking technique is used for curing of large-ardamom by burning huge quantity of wet wood logs esulting in poor quality of dried large-cardamom.

eed for technology upgradation

arge-cardamom is a major cash crop of Sikkim. There s no concept of quality for large-cardamom. In order to ncrease the large-cardamom export there is need to nprove its quality (maintaining natural reddish colour and olatile oil content) to fetch premium price.

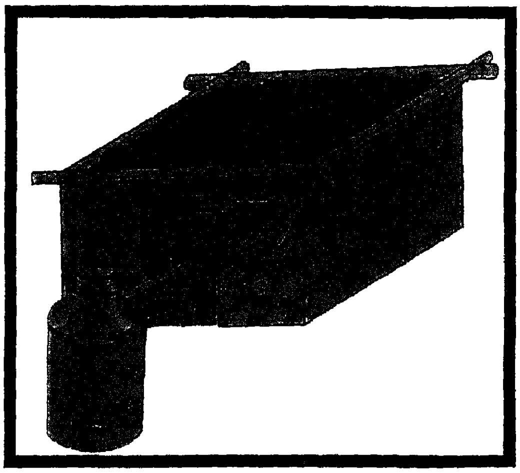


advantages of traditional bhatti system

- The uncontrolled burning of wood logs results in loss of volatile oil (which gives aroma to dried cardamom)
- excessive exposure to smoke gives char like burnt smell to the volatile oil if extracted from dry capsules
- Charring of capsules due to localized over heating

Gasifier system for cardamom drying

Gasifier converts solid wood fuel into gaseous form, which in turn can be used under controlled burning conditions to provide heat required for removing moisture from cardamom capsules in drying process. TERI has developed an advanced gasifier based large-cardamom dryer system in its laboratory at Gual Pahari in Haryana. A prototype unit was successfully field tested in Sikkim, at one site each in all the four district of Sikkim, in order to monitor its field performance and receive feedback for further improvising the system design. In the last large-cardamom harvesting season the improvised system was successfully used by more than 25 farmers in north Sikkim to obtain improved quality large-cardamom with better appearance and more volatile oil content without any burnt or char like smell.



Advantages of TERI's improved gasifier dryer

- Controlled burning helps in retaining more volatile oil (2.5-3.0% as against 1.5-1.7% in traditional system)
- Clean burning of gaseous fuel results in better quality volatile oil without any burnt or char like smell
- Retains natural reddish colour of large-cardamom

Beyond energy and environment

The technology upgradation for curing of large-cardamom in Sikkim will definitely improve energy efficiency helping preservation of natural forest of the state. The improved quality large-cardamom will also help increasing the income generation for farmers as trial test marketing of improved quality large-cardamom obtained from gasifier-based system got encouraging response in major trading centers of Delhi, Amritsar, Kanpur and Lucknow. Indications are that it may fetch about 10-15% premium initially over traditionally cured large-cardamom. More oil content without burnt smell can open new dustry for large-cardamom by way of extracting its oil. Presently oil from small-cardamom fetches very high price of about 8,000 to 12,000 per liter.

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Fax: (011) 4621770/4632609
e-mail: sanman@teri.res.in

Annexure 2

List of industries/traders contacted during trial test marketing of large-cardamom oil

List of industries/traders contacted during trial test marketing of large-cardamom oil

Essence, flavouring agent suppliers

1. Ajanta Chemical Industries
221, Peeragarhi
New Delhi 110 041
2. Aryan Flavours
B-8, Sector 6
Noida – 201 301
3. Azad Bharat Chemical Co
2127, Tilak Bazar
New Delhi – 110 006
4. Gogia Chemical Industries
A127, Okhla Industrial Area (Phase II)
New Delhi – 110 020
5. Hamarain Gokal Chand
B-3/1, Lawrence Road
Industrial Area
Delhi – 110 035
6. High-Tech Flavours
Saraswati Niwas
V S Ahashe Road,
Dadar, Mumbai – 400 028
7. Mehta Brothers
1482, S P Mukherjee Marg
Delhi – 110 006
8. Ultra International Ltd
304, Avg. Bhawan
M – 3, Connaught Circle
New Delhi – 110 001

Ayurvedic medicines

1. Asht Vaidyan Ayurveda Med & Panchkarm
C-111, West Patel Nagar
New Delhi – 110 008
2. Baijnath Pharmaceuticals
82-A, Nanak Pura
Moti Bagh
Deep Sikha Building
New Delhi
3. Combil Organochem Pvt. Ltd
803, Mercantile House
15 K G Marg
New Delhi – 110 001
4. Dabur India Limited
7, Noida Export Processing Zone
Noida

Devi Sahai Mohan Lal
2087, Katra Tobaccoo
Khari Baoli
New Delhi – 110 006
Guapha Remedies Pvt Ltd
A-24, Sector – 7
Noida – 201 301
Maharishi Pharmaceuticals Pvt Ltd
40/2, New Rohtak Road
New Delhi – 110 005
Native Drugs Pvt Ltd
30, Vijay Nagar
Amritsar – 143 001
Shree Baidyanath Ayurved Bhawan
127, Gusainpur,
Jhansi – 284 002
Madhya Pradesh
Shree Baidyanath Ayurved Bhawan Ltd
28, Ishwar Nagar
New Delhi – 110 065

d products

Gogia Sales Agencies
A-127, Okhla Industrial Area
Phase – II, New Delhi – 110 020
Gulati & Co
148, SP Mukherjee Marg
New Delhi – 110 006
Harbans Lal & Co
C-127, Fruit Market
Azad Pur, New Delhi – 110 033
Indra Baked Products
20, Yamuna Marg
Civil Lines
Delhi – 54
K K Industries
169-DS New Raj Nagar
New Delhi – 110 060
Mahashian Di Hatti (P) Ltd
9/44, Kirti Nagar
New Delhi – 110 015

enthol and peppermint products

Adukia Chemicals
Lane No 1, Plot No. 9
Sheetla Mata Colony
Gurgaon

Golden Menthol Exports Pvt Ltd
A-95/3, Wazirpur Industrial Estate
Delhi – 110 052
Rajhans Aromatics
201, IP Tower Commercial Complex
Wazirpur, New Delhi – 110 052
Snow Stock
B-140, Phase – II
Noida
Vardhman Crystal
E-49/103, Jawahar Park
Laxmi Nagar
Vikas Marg, Delhi – 110 092

mes, cosmetics and toiletries manufacturers and dealers

Ajay Home Products Limited
C-114, Naraina Industrial Area
Phase – I
New Delhi – 110 028
Allen Deep International
C-2/6 Pargati Market
Ashok Vihar
New Delhi – 110 052
Ashoka Marketing Co
Orient Shaving Cream & Tooth Paste
2160, Bahadurgarh Road
Sadar Bazar
Delhi – 110 006
Bhai Ji Attarwale
853, Qutab Road
Sadar Bazar
Delhi – 110 006
BMV Fragrances (P) Ltd
A-12, Vikaspuri
New Delhi – 110 018
Gulabsingh Johrimal
320, Dariba Kalan
Delhi – 110 006
Hindustan Laboratories
B-932, Shastri Nagar
Delhi – 110 052
Indian Cosmetic Industries
Village Asola-Bund Road
Fatehpur Beri
New Delhi – 110 030
J K Industrial Perfumers
A7/7, Krishna Nagar
New Delhi – 110 051

Jayna Exports
58-B, Madan Park
New Delhi – 110 026
Kanta Chemical Pvt Ltd
133, Tilak Bazar
Delhi – 110 006
Mittal Aroma Essential Oil Pvt Ltd
2279 Gali Hingabeg
Tilak Bazar, New Delhi – 110 006
Rishabh & Co
G-22, Keshavpuram
New Delhi – 110 035
Ultra International Limited
304, AVG Bhawan
M-3, Connaught Circus
New Delhi – 110 001

Annexure 3

List of participants: project review workshop - 27 April 1998 held at Gangtok

List of participants: project review workshop - 27 April 1998 at Gangtok

Spices Board (3)

1. Dy Director (Dev) - Mr Johny Kutty
2. Dy Director (Res) - Dr S Varadarasan
3. MIO - Mr P P Kenel

Department of Horticulture/Agriculture (14)

1. Secretary Horticulture - Mr H R Pradhan
2. Secretary Agriculture - Mr G K Gurung
3. Director Horticulture - Mr S K Gurung
4. Additional Director Horticulture - Mr J R Subba
5. Senior Project Officer - Mr U Bhutia
6. Project Coordinator/Horticulture - Mr C P Basnet
7. Dy Director Marketing - Mr D K Mukhia
8. Joint Director West - Mr Nima Bhutia
9. Joint Director South - Mr B B Lama
10. Joint Director North - Mr Y K Pradhan
11. Joint Director East - Mr K Bhutia
12. HO, Mangan - Mr K Yazor
13. HO, Chungthang
14 HI, Dzongu

ISPS (3)

1. Liaison Officer - Dr P J Joseph
2. New Liaison Officer - Dr C K Rao
3. Project Executive - Mr Navraj Gurung

TERI, New Delhi (3)

1. Senior Fellow - Dr V V N Kishore
2. Fellow - Mr Sanjay Mande
3. Technical Assistant - Mr L B Thakur

Planning and Development Department (1)

1. Joint Secretary

G.B. Pant Institute (1)

1. Research Scholar

Simfed (1)

1. Managing Director

NABARD (1)

1. Officer Incharge

Lead Bank (SBI) (1)

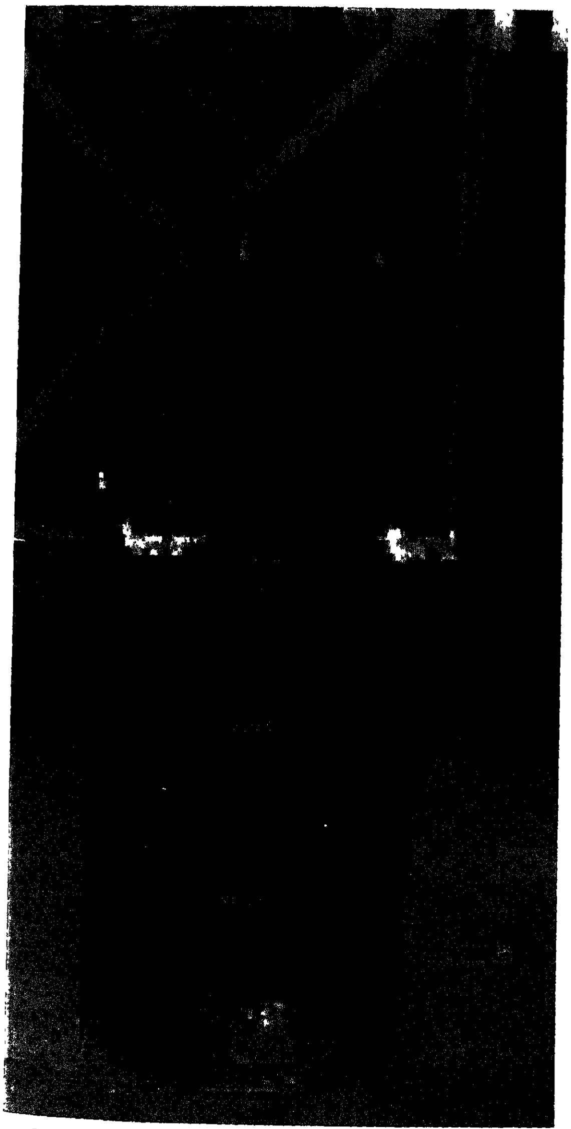
1. Manager

Annexure 4

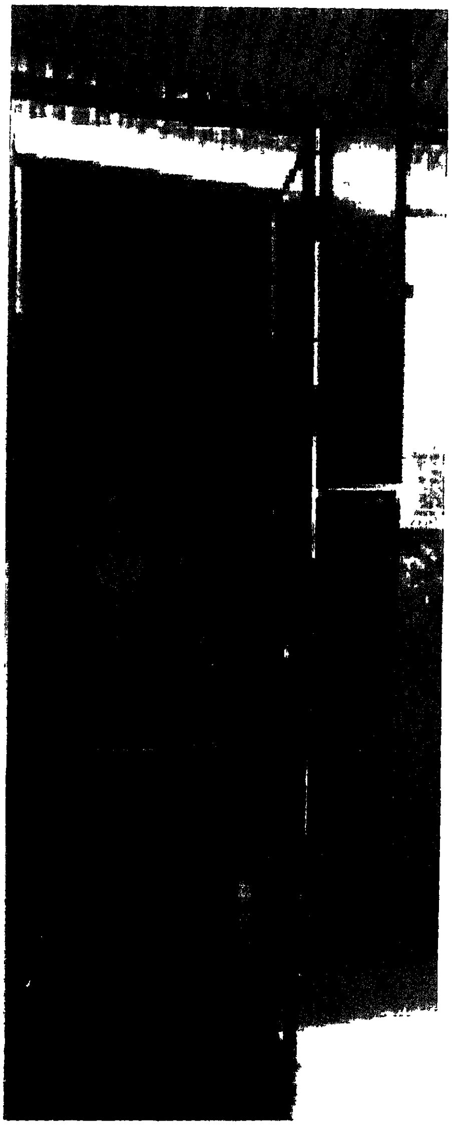
Development of gasifier system for drying of large-cardamom (concept-pilot plants) - Selected transparencies from presentation made by Mr Sanjay Mande in Project Review Workshop

Development of gasifier system for drying large-cardamom (Concept to pilot plants)

Proof of concept at TERI (Summer 1996)



Using tandoor as updraft gasifier

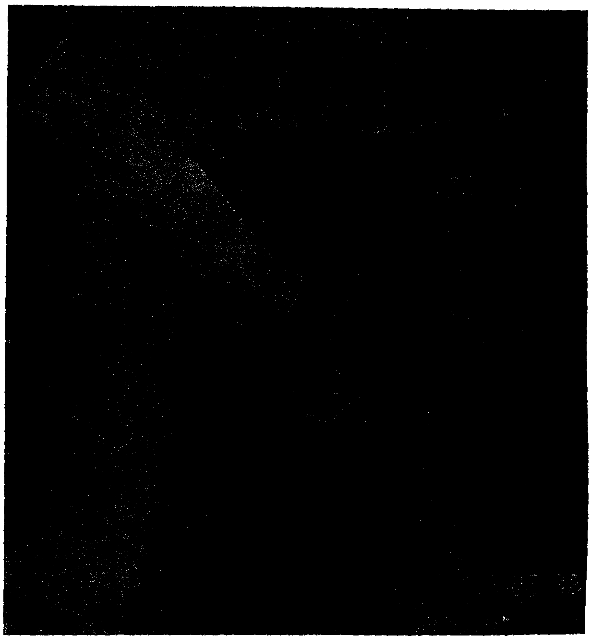


Modified gasifier in drier

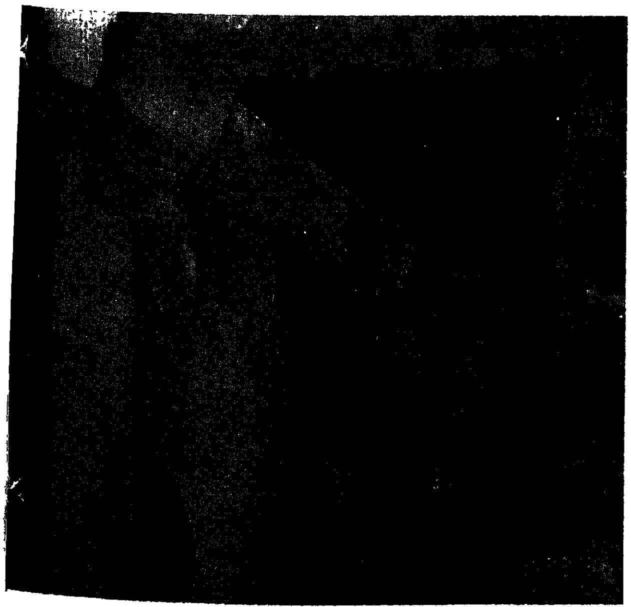
Development of gasifier system for drying large-cardamom (Concept to pilot plants)

Trial field testing at Kabi (Winter 1996)

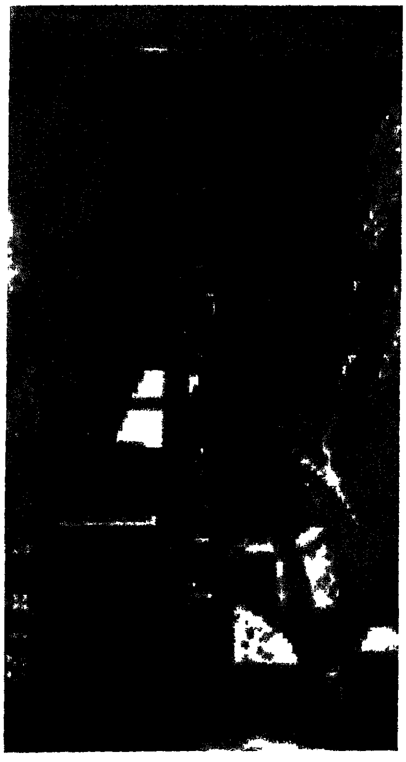
asifier in operation at
abi



Duct attached to takeout smoke



Modified fuel charging duct

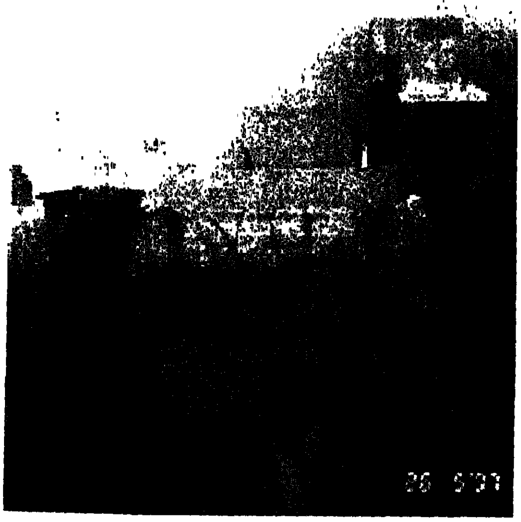


Configuration changed

Development of gasifier system for drying large-cardamom (Concept to pilot plants)

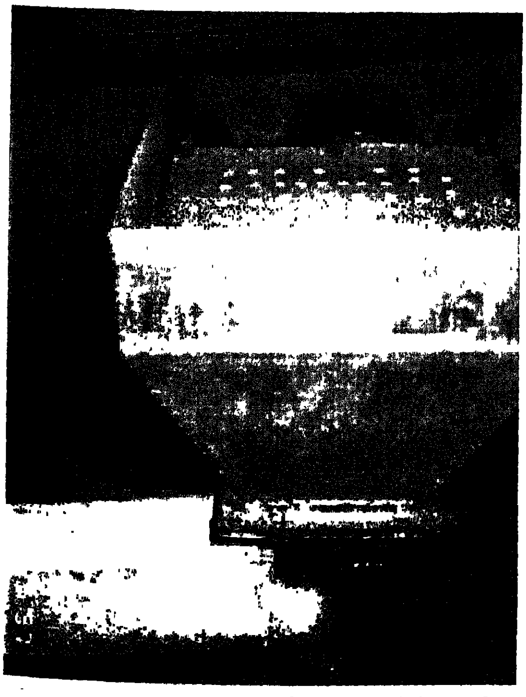
Improving system design at TERI based on feedback

(A) Burner design optimization (Summer 1997)



Open square burner with central air pipe: gave smoky operation

Venturi burner: gave good performance but very tall



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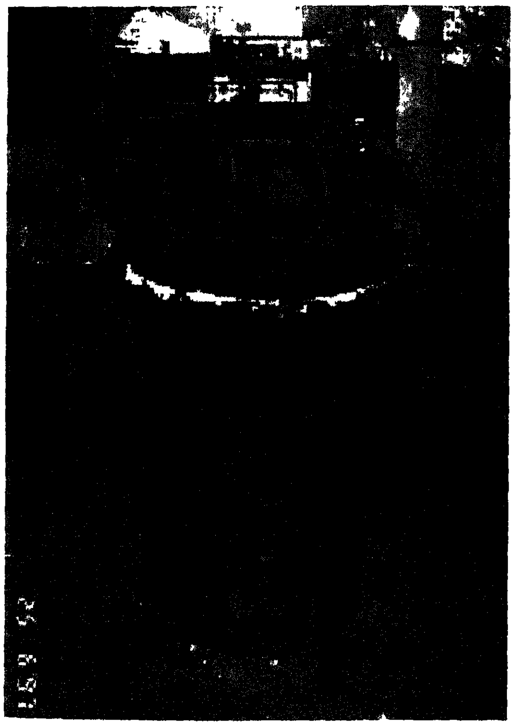
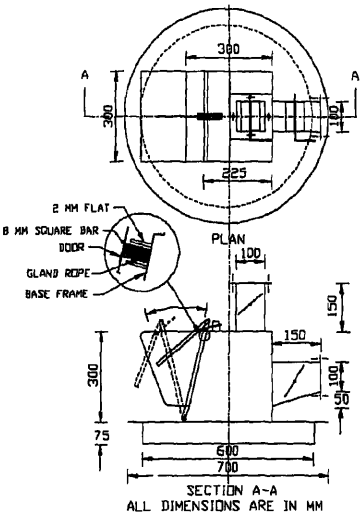
Development of gasifier system for drying large-cardamom (Concept to pilot plants)

Improving system design at TERI based on feedback

B) Modifying fuel charging system: easy to operate and feed larger size wood pieces (Summer 1997)

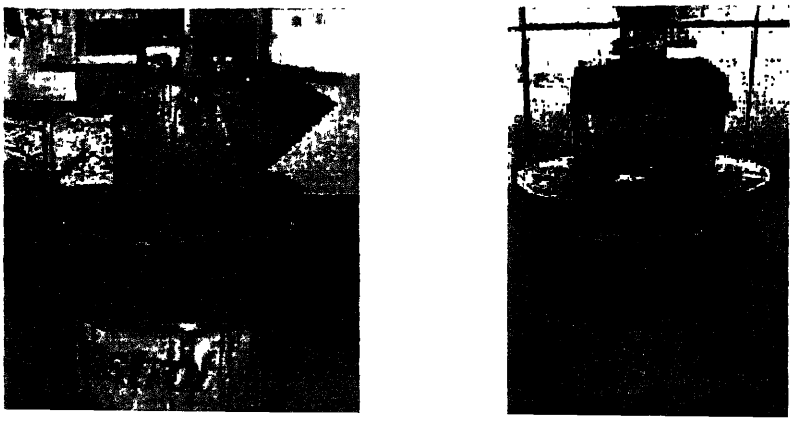


Gasifier cover with top rectangular opening: could accomodate larger wood pieces but still cumbersome



Schematic diagram of gasifier top cover with fuel charging lever mechanism

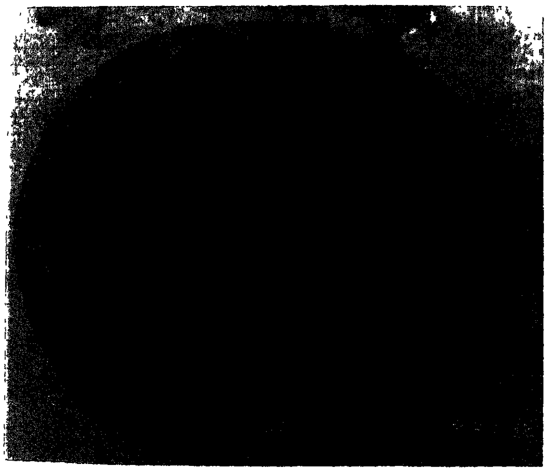
Gasifier cover with fuel chrging door with lever mechanism



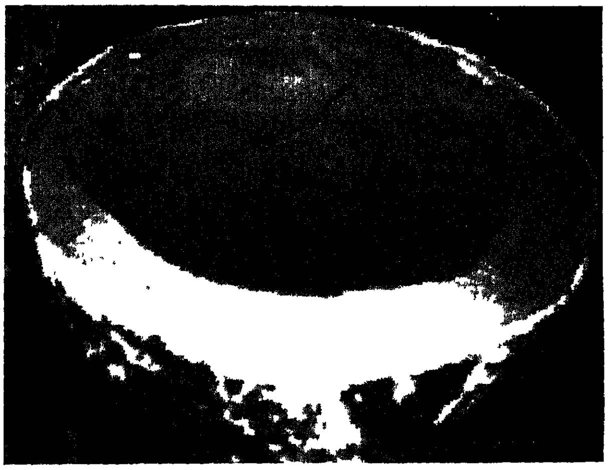
Development of gasifier system for drying large-cardamom (Concept to pilot plants)

Improving system design at TERI based on feedback

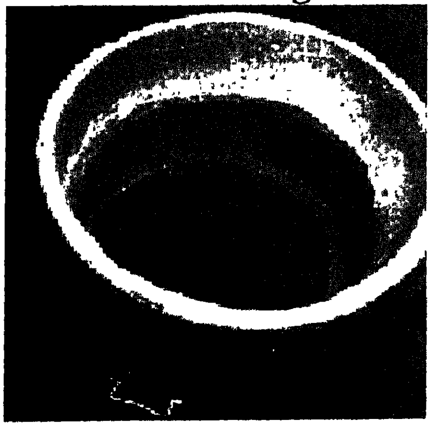
(C) Insulation material: reducing weigh, cost and improving transportability (1996 & Summer 1997)



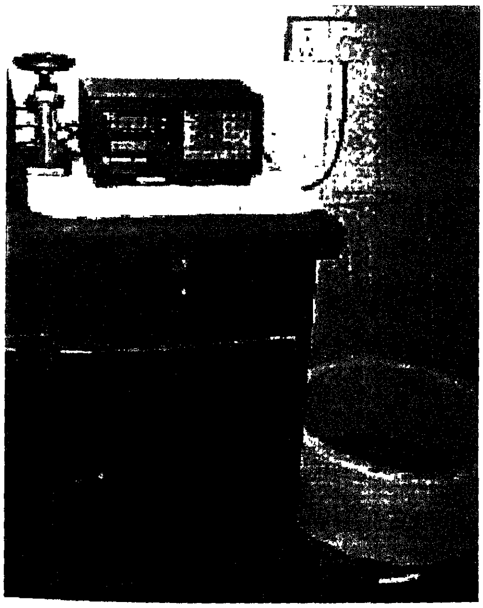
In situ castable insulation lining throughout gasifier at Kabi



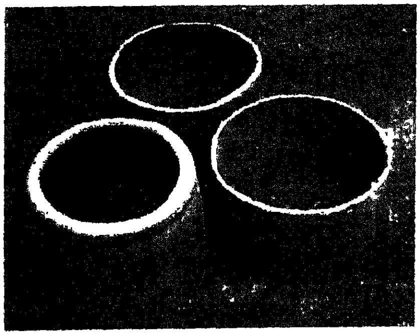
Local (at Kabi) clay insulation gave cracks as casting dried up



Insulation rings with reducing thickness



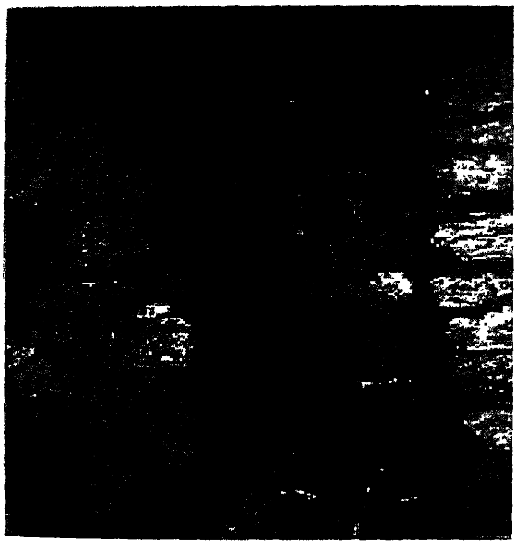
Individual castable ring weighing within transportable limit



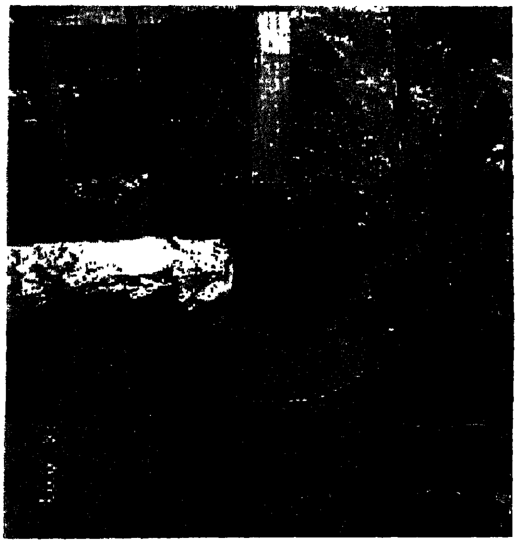
[illegible] with mud wings:

Development of gasifier system for drying large-cardamom (Concept to pilot plants)

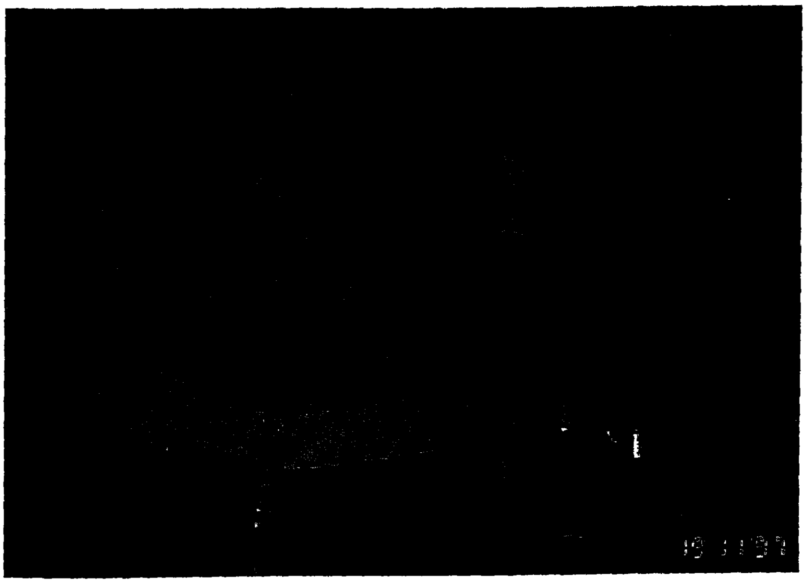
Extended field testing in all districts of Sikkim for wider demonstration and thourough performance monitoring



Close performance monitoring of the system performance



Gasifier system installed at Assam Lingzey (East Sikkim)

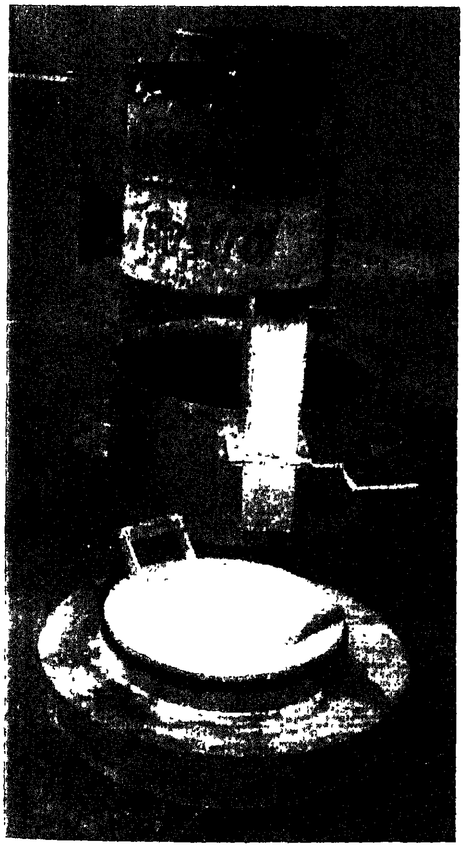


Portable tourist tent installed in the fields of
d the clock system

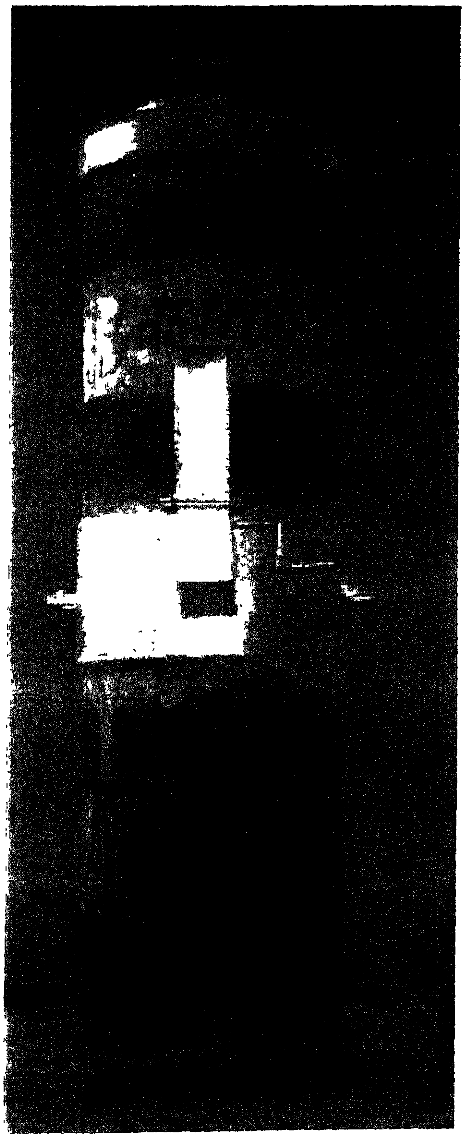
Development of gasifier system for drying large-cardamom (Concept to pilot plants)

Development of Mark-2 system design (Summer 1998)

(A) Provision of extended fuel storage bin: increases fuel charging interval, stable gas burning, ease of fabrication



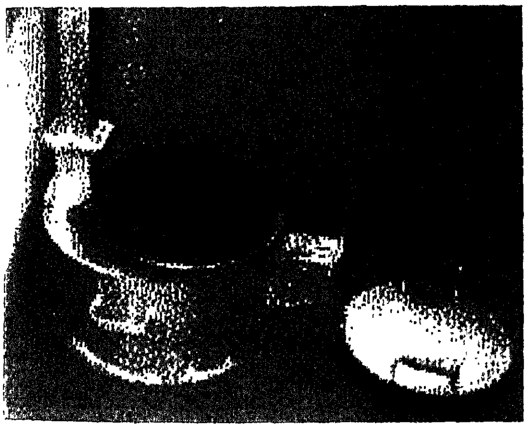
System components of Mark-2 gasifier



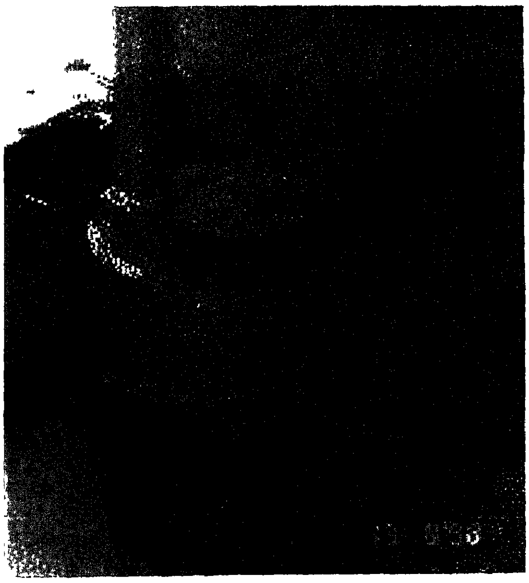
Assembly of Mark-2 gasifier system

Development of Mark-2 system design (Summer 1998)

(B) Provision of larger water seal gasifier door: quick fuelwood charging, allows use of larger size wood pieces



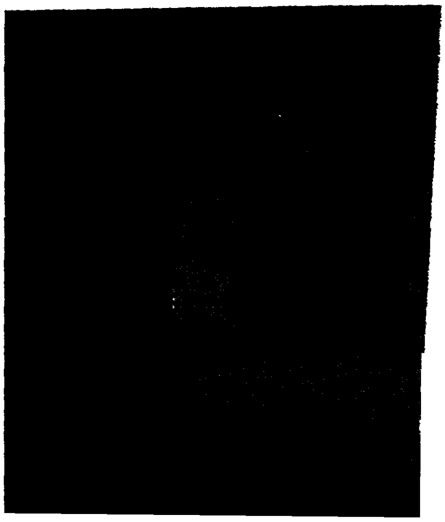
Water seal door components



Assembly of water seal door

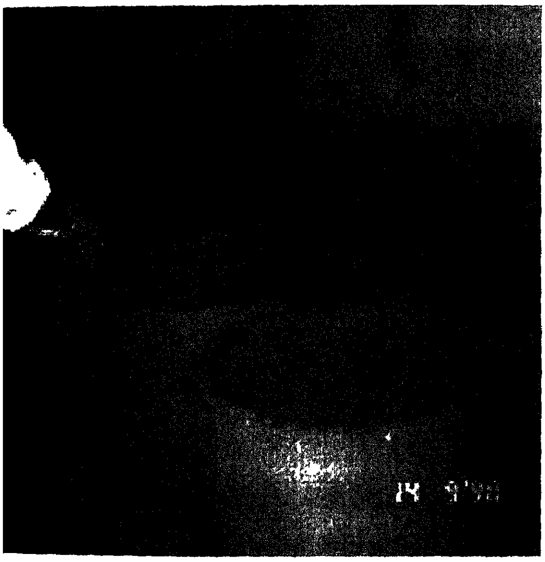
(C) Use of local bamboo as duct insulating material

(D) Optimization of multiple gas burner



Development of gasifier system for drying large-cardamom (Concept to pilot plants)

Mass production of pilot (Mark-2) plants (Winter 1998)



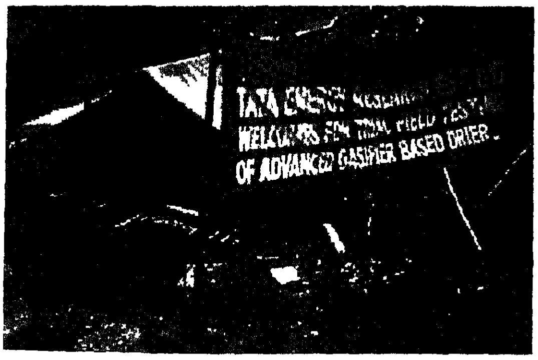
sting and curing of insulation rings

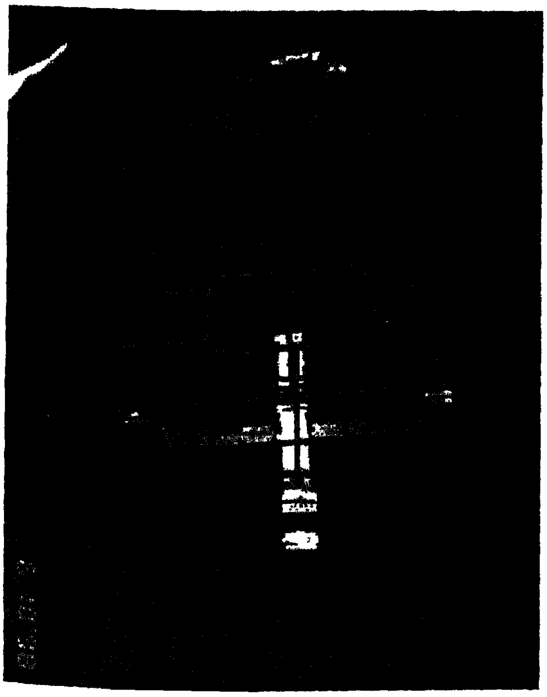
Fabrication of system components in Ranipool in Sikkim

Gasifier units transported to pilot plants in Mangan

Development of gasifier system for drying large-cardamom (Concept to pilot plants)

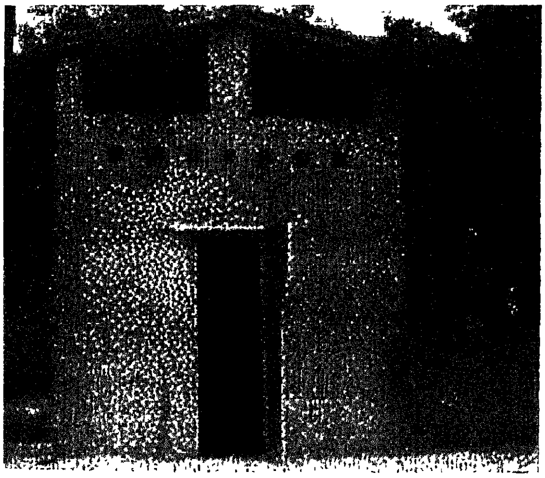
Installation of pilot plants in north Sikkim (Winter 1998)


TATA ENERGY RESEARCH
WELCOMES YOU FOR TRIAL FIELD TESTING
OF ADVANCED GASIFIER BASED DRIER.

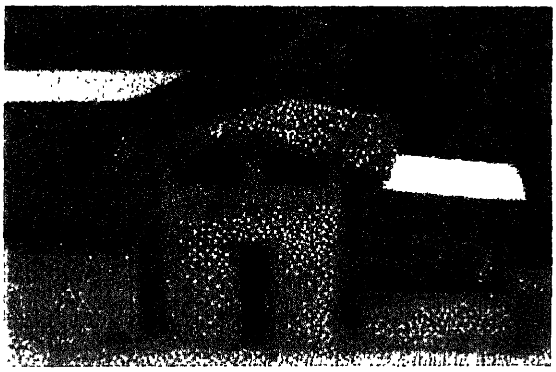


Development of gasifier system for drying large-cardamom (Concept to pilot plants)

Development of improved bhatti design (Summer 1998)



Front view of improved *bhatti*



Aerial view of improved *bhatti*

Annexure 5

Study of large-cardamom oil - Selected transparencies from presentation made by Mr Sanjay Mande in Project Review Workshop

Study of large - cardamom oil

teri

Botany of large- cardamom

Family : *Zingiberaceae*
Genus : *Amomum*
Species : *Subulatum*

- Total 150 *Amomum sp.* known, from which 30 species are known to be cultivated in India.
- Medicinal species of

  China : *A. amarum* F P Smith
  A. scostatum Benth
  A. xanthiodes Wall

  Combodia : *A. krevanch* Pierre

  Malaya : *A. amarum* F P Smith
  A. aromaticum Roxburgh
  A. echinosphaera K Schum
  A. krevanh Pierre
  A. xanthioides Wall

  Malaya : *A. maximum* Roxburgh

  Gold Coast : *A. granumoaradisi* Linn.
  A. melegucta Rosc.

  Mauritius : *A. angustifolium* Sounerat

  India : *A. sabulatum* Roxburgh
  A. costatum Benth
  A. *aromaticum* Benth
  A. *xanthioides* Wall

Varieties & capsule characterstics

riety	Colour of capsule	Colour of seed	Capsule size
wney	Light brown	Brown	Medium
d sawney	Greyish brown	Greyish brown	Large size
lsey	Brown	Light brown	Large sized
hite golsey	Pinkish brown	Black	Large sized
hite green lsey	Dark black	Black	Medium to large
hite ramna	Yellowish		Small size

Quality considerations

Market influencing qualities

- Size : Larger size fetches higher premium. *Golsey* (Mangan) has more demand and popularity

- Colour : Attractive natural colour increases market demand and fetches better price

- Moisture content
  - Higher the moisture, lower is the price
  - Moist capsules are prone to fungal infection
  - Standardization of moisture content < 10% (wb) needs to be implemented for longer safe storage

- Proper processing
  - Localized over heating results in splitting of the capsules
  - Uncontrolled heating results in loss of volatile oil which is responsible for its aroma/ taste
  - Low oil content with burnt smell reduces its industrial usage value (both flavoring and medicinal)

- Presence of tail
  - Though adds to weigh, reduces the quality look, thus reclaims less price

Yield & volatile oil of large cardamom

YIELD

Variety	Wt. of single capsule	Capsules/ clump	Yield/ ha dry capsule	Volatile oil (%)
Golsey dwarf	0.91	26	284	3.32
Golsey tall	1.00	39	481	3.31
White golsey	8.80	70	696	3.21
Dwarf bush	0.76	389	1314	2.46
Sawney tall	0.85	149	568	2.50
Red sawney	0.75	321	1069	2.52
Ramsey	0.67	162	484	2.31
Sawney small	0.56	130	468	2.21
White ramna	0.52	288	665	1.95

- Though *dwarf bush* has low oil content, it may be more attractive in terms of yield per hectare

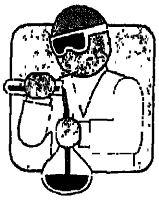
- *Golsey* seems to be superior in respect of oil content

Chemical composition Of seeds

Moisture : 8.5%
Protein : 6%
Volatile content : 2.8%
Crude fibre : 22%
Starch : 43%
Ether extract : 5.3%
Alcohol extract : 7.0%
Ash : 4%
Calcium : 666.6 mg/100 g
Magnesium : 412.5 mg/100 g
Phosphorus : 61.0 mg/100 g
Fluoride : 14.4 ppm

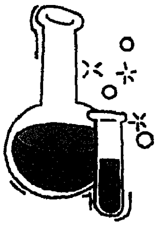
Contains:
Glycosides
Petunidin 3,5 diglucoside
Leucocyanidin 3-o-β-D-glucopyranoside
Subulin
Chalcone
Cardamonin
Alpinetin

Volatile oil content



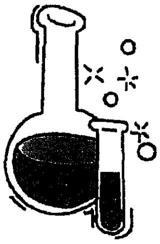
Variety	Volatile oil (%)
Golsey dwarf	3.32
Golsey tall	3.31
White golsey	3.21
Dwarf bush	2.46
Sawney tall	2.50
Red sawney	2.52
Ramsey	2.31
Sawney small	2.21
White ramna	1.95

Composition of small - cardamom volatile oil



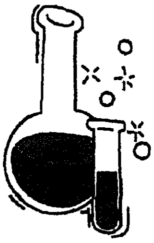
Constituents	Concentration (%)
α-terpineol	45
Myrcene	27
Limonene	8
Menthone	6
β-phellandrene	3
1,8 cineol	2
Sabinene	2
Heptane	2

Composition of volatile oil



Constituent	*Ramsey*	White *Ramna*	Red *Sawney*	*Sawney*	White *golsey*	*White green golsey*	*Golsey*
Sabinene	3.7	4.6	3.9	3.4	3.1	4.4	4.2
α-terpinene	8.6	7.0	8.7	4.7	7.0	8.6	8.7
Cineol	77.0	78.0	89.0	85.0	81.0	80.0	78.0
α-bisabolene	7.1	2.8	2.8	1.1	2.3	3.0	3.1
β-terpinol	1.0	-	-	-	-	0.7	-
α-terpineol & α-terpinyl acetate	6.1	6.8	5.8	4.8	6.4	3.5	5.1

Composition of volatile oil



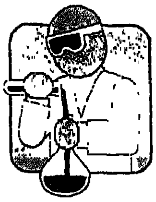
- *Amomum subulatum* (Brian M. Lawrence)

Constituents	Concentration (%)
1,8-cineol	74.0
Limonene	10.3
α-terpineol	5.6
β-pinene	2.4
α-pinene	2.0
Terpinen-4-ol	2.0
Nerolidol	1.0
δ-terpiniol	0.8
Myrcene	0.3
β-cymene	0.2
Sabinene	0.2
α-terpinene	0.2
γ-terpinene	0.2

Industrial application & importance of oil constituents

• 1,8-cineol	Pharmaceutic aid of cough, expectorants and flavors
• Limonene	Fragrance, perfumes, flavor, wetting and dispersing agent
• α-terpineol	Denaturing fat (soap manufacturing), perfumes, antiseptic
• β-pinene	Substitute to α-pinene, intermediate to perfumes and flavoring
• α-pinene	Insecticide, perfume base and manufacture of camphor & synthetic pine oil
• β-cymene	Antihistaminic and antifungal
• Terpinen-4-ol	Respiratory tract disorders and disinfectant
• δ-terpiniol	Respiratory tract disorders and disinfectant
• Myrcene	Intermediate in manufacture of perfume chemicals
• α-terpinene	Manufacture of synthetic flavor of lemon
• Sabinene	
• γ-terpinene	
• Nerolidol	

Oil content in market cardamom & gasifier dried cardamom



Market cardamom : 1.6 - 2.1%

Gasifier dried cardamom of 1997 batch : 2.03 - 2.65%

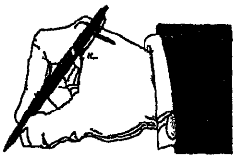
Gasifier dried cardamom of 1998 batch : 2.20 - 3.0%

Medicinal usage

- Used as diuretic in case of gravel of kidney
- Used in digestive disorders, marked by scanty and viscid secretion of intestine, it promotes elimination of bile(Kirtikar and Basu)
- Used for the treatment of cutaneous infections as both *Amomum* and *Elettaria cardamomom* oil enhance the penetration of drug through skin (Huang, Hsu *et al*)
- Used against keratinophilic fungi(CA)
- Used to subside the post-operative side effects(Liu & Wu)
- 30 grains with quinine used for neuralgia(Kirtikar & Basu)
- Applied to eyes to allay inflammation
- Used in gonorrhea as an aphrodisiac
- Not used as an antidote to snake venom or scorpion venom
- Used as tonic to cardiac and liver
- Used for Stomachic
- Alexipharmic
- Vomiting
- Enlarged spleen
- Thirst
- Itching
- Abdominal pain
- Used in disease of rectum, mouth and head

In general it can be said that it is used for halitosis, flatulence, hyperacidity, vomiting diarrhoea, dysentery, skin diseases, wounds, ulcer, neuralgia, cardiac, odontalgia, cephalalgia, liver congestion, splenomegaly, cough, bronchitis, strangury, fever, hyperdipsia, gonorrhea etc.

Conclusions



- Although the present large - cardamom oil is of inferior quality as compared to that of small cardamom, but many high priced constituents of small - cardamom oil are present in all varieties of large - cardamom
  e.g sabinene, cineole , perpineol, terpineol and terpinyl acetate

- *Golsey* seems to be superior among large - cardamom varieties as it contains 3.2% oil and has all those constituents which are present in the small cardamom oil

- Presence of all these compounds of small-cardamom in the oil of *Amomum subulatum Golsey* variety greatly determine the value of its oil as a substitute for small - cardamom